Marine Corps
Modeling and Simulation
Master Plan

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From: Commandant of the Marine Corps

Subj: MARINE CORPS MODELING AND SIMULATION MASTER PLAN (MCMSMP)

1. The Marine Corps Modeling and Simulation Master Plan (MCMSMP) is approved. The MCMSMP articulates the vision and associated end states for the Marine Corps modeling and simulation (M&S) environment. It provides a common structure for coordinating efforts within the Total Force, defines relationships between participating organizations, describes key technical issues and assesses the current state of M&S technology. This plan in conjunction with the Marine Corps Modeling and Simulation Investment Plan (MCMSIP), provides a foundation for developing the Marine Corps modeling and simulator related input into the Program Objective Memorandum (POM) as well as a basis for reassessment and reprogramming during upcoming fiscal years. The MCMSMP was designed for easy understanding and wide distribution to inform all organizations (active and reserve components) within the Marine Corps of where we are going in terms of modeling and simulators. Read it thoroughly, review it frequently, and incorporate its contents into your plans. By using this plan we will all be in step as we move toward capitalizing on the vast opportunities presented by modeling and simulation to improve the combat readiness of the Total Force.

2. Comments concerning this plan should be addressed to the Commanding General, Marine Corps Combat Development Command (C 46), Quantico, Virginia 22134-5021.

C. E. MUNDY, JR.

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Executive Summary

The Marine Corps will maximize warfighting capability by exploiting interoperable world class modeling and simulation (M&S). The Corps has stepped up to take full advantage of the explosion in information and communications technologies to improve the performance of the Total Force. While getting full measure from stand-alone models and simulators, the Marines will move rapidly to incorporate the many advantages of advanced distributed simulation. It is critical to apply these technologies to the five functional areas of education, training and military operations; research and development; test and evaluation; analysis; and production and logistics. By ensuring that it simulates before it builds, buys or fights, the Corps can enhance training and readiness while reducing costs.

The Marine Corps Modeling and Simulation Master Plan articulates the vision, objectives and management framework for the Marine Corps simulation environment. It provides a common structure for coordinating efforts within the Total Force, defines relationships between participating organizations, and describes key technical issues. Basically, all models and simulators with a development or acquisition cost of $25,000 or greater, are addressed by this plan. The plan does not address the costs associated with implementing a Marine Corps Advanced Distributed Simulation (ADS) environment. These costs and a time-phased acquisition approach for models and simulators are the subject of a separate Modeling and Simulation Investment Plan that is currently being developed.

The Master Plan addresses the capabilities the Marine Corps is expecting in its vision of M&S by delineating eight desired end states:

1. Exercise any size Total Force MAGTF as part of combined or joint operations from home bases, aboard ship, or forward deployed through the seamless integration of live, virtual, and constructive simulations.

2. Conduct mission planning in a distributed environment.

3. Conduct mission preview and rehearsal on land or at sea at all levels, from the individual marine to MEF, within 48 hours of notification.

4. Validate Marine Corps requirements and doctrine using M&S as a primary tool.

5. Participate in the fundamental improvement of the DOD acquisition process by simulating before "we buy, build, or fight"

6. Merge M&S and command, control, and communications systems.

7. Support every major weapon system in the Marine Corps with a simulator that can be networked into a common synthetic environment.

8. Use M&S as a primary decision support tool.

The Master Plan describes 14 policy and management objectives to chart a course to advance the Marine Corps towards its vision of using M&S to improve the Total Force:

1. Capture the best of legacy stand-alone models to be used while building towards more distributed capabilities.

2. Use ADS to support the training, exercising, and operating of the Total Force.

3. Promote the use of M&S across all five functional areas.

4. Assume a pro-active role within the DOD M&S community.

5. Exploit opportunities for joint and cooperative M&S development.

6. Promote the use of virtual prototyping in the combat development process.

7. Establish centralized coordination/control and decentralized execution of M&S.

8. Establish procedures and guidelines for the quality control and conduct of M&S verification, validation, and accreditation.

9. Establish procedures and guidelines for the conduct of M&S configuration management.

10. Implement procedures and guidelines for M&S information management.

11. Implement procedures and guidelines for M&S requirements and resource management.

12. Leverage the efforts of other DOD components, other government agencies, industry and academia.

13. Enhance technology development and transfer.

14. Develop a M&S Investment Plan.

The Master Plan outlines an implementation strategy to achieve the desired end states. Policies that are realistic, workable, adaptive and centered on meeting the goal of simulating before we build, buy or fight are introduced. An organizational structure that supports the implementation of M&S as an integral part of the way the Marine Corps does business is described. It includes a Marine Corps Modeling and Simulation Management Office (MCMSMO) to serve as a service wide focal point for M&S and provides for a structure that parallels the OSD framework of an oversight committee, a working group, and sub working groups for specific M&S issues. The implementation strategy also identifies two primary locations for developing advanced distributed simulation capabilities — the Marine Corps ADS Demonstration Sites at the Marine Corps Air-Ground Combat Center (MCAGCC) Twentynine Palms and Marine Corps Combat Development Command (MCCDC) Quantico. Other sites, including all three MEFs and MARRESFOR, will have an M&S capability. This capability will eventually be extended throughout the Marine Corps to include deployed MEUs.

An essential part of M&S implementation is an investment strategy. The Master Plan presents the following investment strategy with its three straightforward components:

1. Maximum leveraging of M&S efforts sponsored by the other Services, other DOD and government agencies, industry, and academia to meet Marine Corps requirements.

2. Obtaining non-existing M&S capabilities through cooperative development effort whenever possible.

3. Embarking on M&S development efforts solely involving the Marine Corps only when they cannot be obtained through leveraging or cooperative development.

Technologies necessary to achieve the desired end states are identified in Chapter 2, and assessed in appendix A. Current capabilities and future capabilities with a projected time frame for maturity are examined. The assessment indicates that the end states are technologically achievable in windows ranging from as early as 1998 to as late as 2010.

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Introduction

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Section 1.1
Background

The Marine Corps will acquire and apply modeling and simulation (M&S) technologies effectively and efficiently to support Marine Corps roles and missions.

The dismantling of the Warsaw Pact and the end of the Cold War present the Marine Corps with a series of new challenges. The future Marine Corps will be a smaller, complementary mix of the Total Force (e.g., Marine Corps active and reserve components). The Marine Corps will be required to move rapidly against regional contingencies, and to carry out a diversified list of missions including those short of armed conflict. The Marine Corps' ability to train the Total Force for this proliferation of contingencies and missions will be hampered by two trends, the loss or encroachment of training areas, both at home and overseas, and the reduction in the overall defense budget.

As the Marine Corps prepares for its future role, new equipment, weapons, doctrines, and operational concepts will require extensive evaluation, all at potentially high cost. The acquisition process was in overdrive during the 1980s resulting in the research, development, and fielding of more and more sophisticated weapons systems and equipment. Funds were available to fuel the process and keep the United States ahead in the technology race. These conditions no longer exist. Requirements will continue to be developed but the funding will not be available to sustain the development process. The Marine Corps will have to find more efficient and less costly ways to define requirements, evaluate solutions, and refine system and equipment designs.

The Marine Corps recognizes that advances in computer capabilities and modeling and simulation technologies, particularly advanced distributed simulation (ADS), offer significant opportunities for responding to the aforementioned challenges, as depicted in Figure 1-1. An extensive set of stand-alone models such as TWSEAS and Janus-A and simulators such as

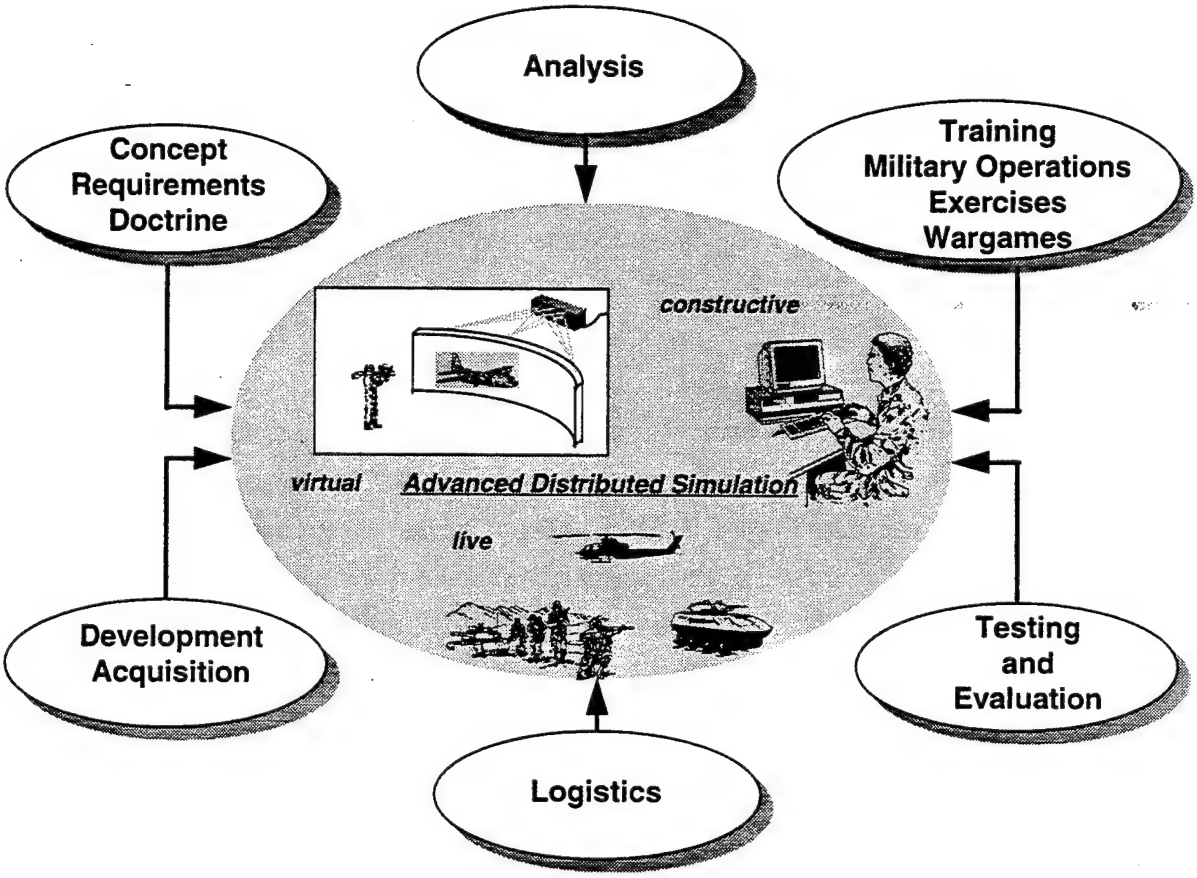

Figure 1-1. M&S Applications Cover a Broad Spectrum

aircraft weapons systems trainers exist capable of a broad spectrum of simulations in terms of the degree of resolution provided and the functional domains supported. The Marine Corps recognizes the important role of these stand-alone models and simulators. They not only enhance training, education, analysis, logistics, planning and the conduct of operations, but also provide the basis for improving future acquisition decisions, systems testing and evaluation, realignment of force structure, and requirements definition. Even greater opportunity for the use of M&S is being provided by technological advances that permit the internetting of the various models and simulators with a common synthetic environment to create an interactive distributed simulation. As the Marine Corps moves toward distributed

simulations, the use of stand-alone models and simulators will remain an important part of the way the Marine Corps does business.

However, implementation of an ADS environment will permit Total Force training without units physically leaving their home bases. Using a common synthetic battlefield saves the cost of moving units or their equipment, and reduces wear and tear on the equipment. ADS provides a commander the opportunity to develop and test operations and contingency plans in a realistic, simulated environment that can also support mission planning and rehearsal.

ADS will permit combat developers to economically and rapidly explore new operational concepts and doctrine, refine warfighting capabilities, define new weapon and equipment requirements that best meet these concepts, and evaluate their impact on operational effectiveness. ADS provides the potential for development of virtual prototypes that can be used to evaluate, select, and refine designs for proposed new systems or equipment well before a physical prototype is built, reducing development cost and time. The use of modeling and simulation and particularly ADS has the potential to revolutionize the combat development process within the Marine Corps.

The Marine Corps has taken a series of steps to accelerate its employment of modeling and simulation technologies. These steps include:

- Establishment of the Marine Corps Modeling and Simulation Management Office (MCMSMO) as the Marine Corps focal point for M&S

- Establishment of an M&S organizational structure that parallels and interacts with the Department of Defense (DOD) management structure delineated in DOD Directive 5000.59

- Conducting the first in a series of Marine Corps M&S Conferences designed to bring the Marine Corps M&S user community together in a common forum

- Successful submission of Defense Modeling and Simulation Office (DMSO) focused calls for funding of Marine Corps projects that benefit the Naval Service and DOD M&S users

- Active participation in Joint M&S initiatives

- Development of a new battle staff training tool, the Marine Air-Ground Task Force (MAGTF) Tactical Warfare Simulation (MTWS)

- Establishment of an ADS demonstration site at Marine Corps Air-Ground Combat Center (MCAGCC), Twentynine Palms, that supports Marine Corps participation in the Advanced Research Projects Agency (ARPA) Synthetic Theater of War (STOW) initiative by developing Marine Corps semi-automated force/automated force (SAFOR/AFOR) representations and experimenting in the use of high fidelity terrain to support training of units, ranging from a company through Marine Expeditionary Force (MEF)

- Planning the establishment of a Decision Making Support Center (DMSC) at Quantico and establishing this location as an ADS demonstration site to experiment with the use of M&S to support analysis efforts

- Development of this M&S Master Plan, which provides a coherent strategy for implementing the Marine Corps simulation environment

The Marine Corps Modeling and Simulation Master Plan articulates the vision, objectives, and management framework for the Marine Corps simulation environment. The plan provides a common structure for coordinating efforts within the Total Force, defines relationships between participating organizations, and describes key technical issues. All models and simulators (whether stand-alone or linked) described below with a development or acquisition cost of $25,000 or greater, are addressed by this plan.

- Models that represent processes, systems, entities, phenomenon and/or forces and their interaction through the use of computer software (constructive)

- Manned simulators and simulations of systems or forces that require computer software (virtual)

- Instrumented tests and exercises where actual troops, weapon systems, and support systems interact and where instrumentation is used to collect, analyze, and distribute data on the force elements, personnel, and equipment (live)

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Section 1.2
Modeling and Simulation Vision

The Marine Corps will maximize warfighting capability by exploiting interoperable world class M&S. A set of clearly defined M&S end states facilitates attainment of this vision.

The Marine Corps M&S Vision is dual oriented. The first orientation is internal and focuses on promoting the use of M&S to improve mission performance across the Total Force. The second orientation is external and focuses on Marine Corps participation in DOD M&S activities.

Advanced distributed simulations (consisting of synthetic environments, models, simulators, and networks) will largely replace the current set of stand-alone models and simulators. Activities of the linked models and simulators will be coordinated and displayed using a common synthetic environment. Combat systems (e.g., tanks, artillery, antitank weapons, etc.), command and control nodes, trainers, logistics and support systems, test systems, constructive models and wargames, and simulated prototype systems and processes will be integrated into the synthetic environment. The Marine Corps ADS environment augments traditional live training at all echelons. Individual combat skills will be sharpened using virtual simulators. These individual simulators will be linked to support interactive individual, crew, and small unit training. Linked M&S will be used to support MAGTF battle staff training at all levels, as well as integrated staff and joint level training. The Marine Corps approach to distributed interactive simulation will permit the Total Force to train *as it fights* while deployed aboard ship, forward deployed, or in garrison.

Commanders and their staffs will test scenarios and conduct mission rehearsals on the synthetic battlefield as different threats are considered. Courses of action (COAs) will be defined and assessed using available M&S tools. Once selected, the COA will be tested and refined on the synthetic battlefield. Using M&S, commanders will have the capability to

estimate the combat readiness of their units as a function of force deployment plans, military strategies, force mix and size, and training readiness.

Modeling and simulation (especially ADS) will become an integral part of the Marine Corps Combat Development Process (CDP). Concepts will be developed and validated requirements will be refined in realistic, simulated environments with sophisticated automated threats using force-on-force and warrior-in-the-loop simulations. Alternative solutions will be developed and evaluated both tactically and technically. The most promising alternatives will be simulated through the use of reconfigurable simulators linked to computerized force-on-force combat models, giving the Warfighter the means to evaluate the performance and contribution of a new system in the environment in which it will operate. The costly "design-build-test" acquisition paradigm will be substantially upgraded with a design process that uses virtual prototyping in a simulated environment to investigate and evaluate the conception, exploration, development, design, testing, production, and sustainment of a combat system throughout its life cycle. As the system progresses through the acquisition cycle, the components (models and simulators) will be refined and new components added (operational models, complementary weapon system models, and logistics models). System designs will be refined prior to incurring the cost of fabrication by exercising virtual prototypes of the system in a simulated environment to evaluate design alternatives and conduct trade-off analyses. As systems are developed they will be integrated into the simulated environment and used to evaluate performance and conduct confirmation tests to revalidate the system for development and production. Subsequent to deployment, the virtual prototype will be exercised in a synthetic environment to define and evaluate life extending product improvements.

Decision-making processes supporting the CDP will be accomplished in a distributed environment centered at the proposed DMSC. This Center will bring together all the capabilities of the Marine Corps ADS environment and Navy M&S in a "one-stop-shop" for analysis that links Commanders in Chief (CINCs), Marine Forces, other Services, Command Centers, Federally Funded Research and Development Centers (FFRDCs), War Colleges, Warfare Centers, University Laboratories, and other analysis centers.

Connectivity is a crucial element in the Marine Corps M&S vision. The Marine Corps will exploit world-wide internetting to bring individuals, crews, teams, staffs, and task organized units into a common environment for training and mission planning, preview, rehearsal, and execution. Marine Corps models and simulators will be interoperable with those of the other Services, allowing the Marine Corps to fully participate in joint and combined exercises. While aboard ship, Navy and Marine Corps integrated models and simulators will use a common simulated environment that supports training and mission planning and rehearsal. Through use of a global network (Global Grid), the Marine Corps will participate in joint training and planning exercises on a common synthetic battlefield that permits development and evaluation of Joint doctrine and tactics.

The Marine Corps M&S vision is oriented to promote the use of M&S to improve mission performance across the Total Force. Simulating before we buy, build, or fight will be an integral part of the way the Marine Corps does business and will optimize the use of available resources. The Marine Corps will incorporate the use of M&S in its doctrinal publications, integrate it into its schools, and exploit its use across the five M&S functional areas.

A set of M&S end states has been developed to guide efforts within the Marine Corps directed at attainment of this vision. These end states are evolving, but as currently envisioned they assist in focusing Marine Corps M&S efforts. They provide definitive guidance that supports the development of M&S objectives. Marine Corps end states are as follows:

- Exercise any size Total Force MAGTF as part of a combined or joint force from home bases, aboard ship, or forward deployed through the seamless integration of live, virtual, and constructive simulations

- Conduct mission planning in a distributed environment

- Conduct mission preview and rehearsal on land or at sea at all levels, from the individual Marine to MEF, within 48 hours of tasking

- Validate Marine Corps requirements and doctrine using M&S as a primary tool
- Participate in the fundamental improvement of the acquisition process by simulating before "we buy, build, or fight"
- Merge M&S and command, control, and communications systems
- Support every major weapon system in the Marine Corps with a simulator that can be networked into a common synthetic environment
- Use M&S as a primary decision support tool

A set of management and technical objectives for attaining the Marine Corps M&S Vision is discussed in the next section.

Section 2
Modeling and Simulation Objectives

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Section 2.1
Policy and Management Objectives

Marine Corps policy and management objectives must chart a focused and coordinated course for participation in all M&S activities to reap the significant benefits they offer while ensuring users' needs are met.

The successful use of M&S throughout the Marine Corps will depend to a large extent on the policies, procedures, processes and guidelines implemented to manage the various aspects of an M&S program. Figure 2-1 provides a list of objectives that promote responsiveness to the individual user's needs while maintaining centralized oversight to ensure the consistent application of established policies, procedures, processes and guidelines.

Capture legacy stand-alone models and simulators to be used in building towards ADS. Many legacy stand-alone models and simulators are currently being used throughout the Marine Corps. These will be retained and evaluated as the Marine Corps moves toward its vision of a fully integrated, distributed simulation environment. Some of these legacy stand-alone models and simulators will be integrated into the distributed environment, others may continue to exist solely in a stand-alone mode, while others will be replaced completely.

Use ADS to support the training, exercising, and operating of the Total Force. As defense budgets are reduced, the Marine Corps will find it more difficult to bring together geographically dispersed units for live exercises. ADS will support global interconnectivity to a common synthetic battlefield, allowing geographically dispersed command, combat, combat support, and combat service support elements to train interactively as they would fight. These ADS supported exercises will not eliminate actual live exercises, but in addition to providing training themselves, will complement live training, increasing the training benefits derived from them. ADS will provide the MAGTF planners with mission planning and rehearsal capabilities prior to mission engagement. In a similar manner, simulators will be used to provide system operators, small units, and individual Marines with critical skills, rehearsal capabilities using the common synthetic environment.

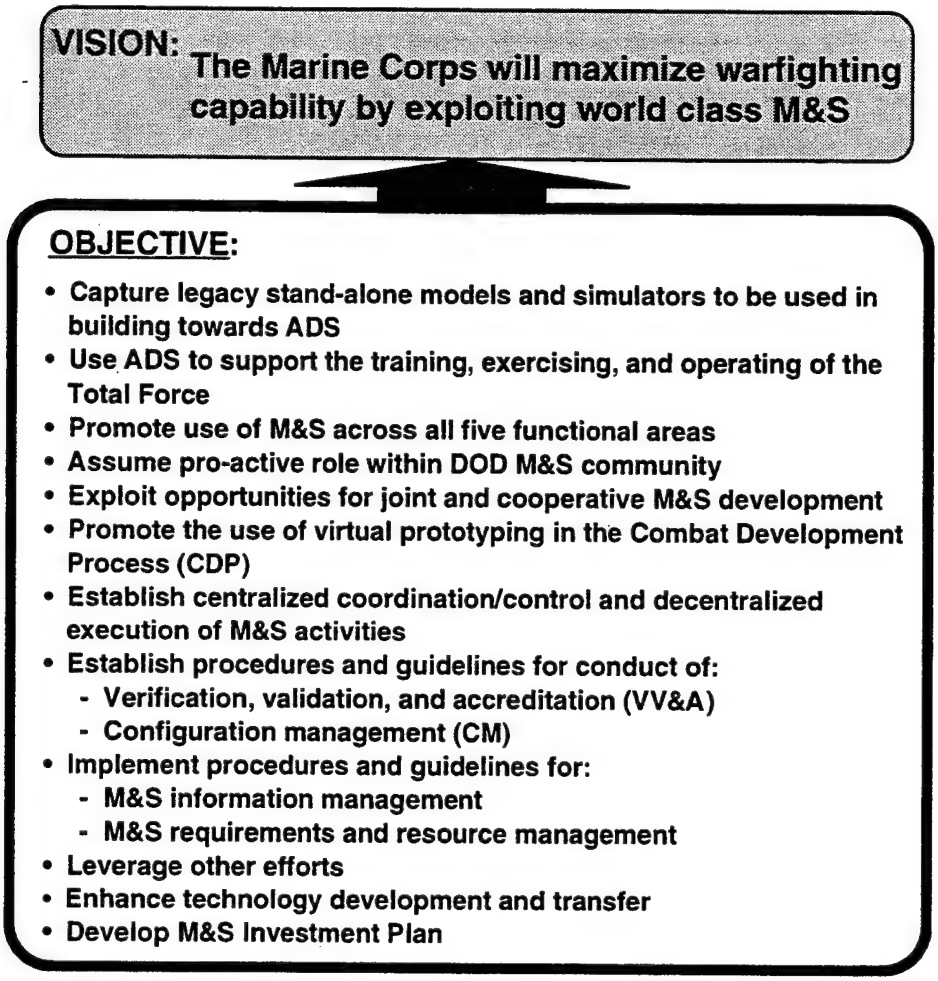

Figure 2-1. Policy and Management Objectives

Promote use of M&S across all five functional areas education, training and military operations; research and development; test and evaluation; analysis; and production and logistics. The current stovepipe approach to the development and use of M&S where each user community develops and uses its own unique set of applications is an inefficient and costly way of doing business that needs to change. By promoting the use of M&S across all five functional areas the Marine Corps can reduce redundant development efforts, integrate the activities of user communities, and reduce acquisition and operating costs.

Assume pro-active role within DOD M&S community. Assuming a pro-active role within the DOD M&S community ensures Marine Corps currency in M&S technological areas and supports leveraging to enhance operational capabilities. Marine Corps attendance at M&S related conferences, seminars, working groups, and demonstrations supports information exchange between DOD, other government agencies, academia, and industry. Active participation on DMSO, Joint, and other Service working groups will ensure proper representation of Marine Corps interests and facilitate identification of opportunities for joint and cooperative M&S development.

Exploit opportunities for joint and cooperative M&S development. The Marine Corps M&S investment strategy relies heavily on leveraging the M&S projects of the other Services and DOD agencies. A key aspect of this strategy is identifying cooperative M&S development efforts that the Marine Corps can exploit. Participation in these efforts provides the Marine Corps the opportunity to directly influence ongoing and planned efforts to ensure they meet Marine requirements with a relatively small investment. Marine Corps involvement also helps ensure that any modeling of Marine Corps capabilities is realistic and accurate.

Promote the use of virtual prototyping in the combat development process. The Marine Corps will promote refinement of the combat development process through the use of "virtual prototypes" on a synthetic battlefield. Virtual prototypes are extremely detailed computer models that have the potential of replacing most, if not all, hardware prototypes. Because hardware is not involved, multiple prototypes are easily configured. This allows the Warfighter to perform large virtual operations to determine the effect of the system in a combat environment instead of merely testing one or two hardware prototypes in situations that have little to do with actual combat. The use of virtual prototypes will allow the Marine Corps to simulate before it "buys, builds, or fights."

Establish centralized coordination/control and decentralized execution of M&S activities. A management approach based on centralized coordination/control and decentralized execution provides effective oversight without incurring the cost of a large and complex organizational infrastructure dedicated solely to management. This concept is

supportable by the current organizational structure with a minimum of disruption. Centralized oversight coordinated by the MCMSMO and the Marine Corps Modeling and Simulation Working Group (MCMSWG) precludes duplication of effort, maximizes attainment of operational capability, and ensures the uniform and consistent application of management procedures for M&S throughout the Marine Corps. Decentralized execution provides an effective approach for managing multiple M&S activities horizontally across functional areas by using organizations currently responsible for performing many of the functions associated with the management of M&S.

Establish procedures and guidelines for the quality control and conduct of M&S verification, validation, and accreditation (VV&A). An effectively managed M&S VV&A process is essential for establishing and maintaining the credibility of Marine Corps models and simulators and subsequently, the confidence that both senior decision makers and users have in their use. Proper verification and validation procedures assure users that a model or simulator functions as originally conceived, specified, and designed, and provides an adequate depiction of the real world. Proper accreditation procedures confirm for the decision makers and users that a model or simulator is acceptable for its intended use. Establishment of uniform procedures and criteria for M&S VV&A ensures that as the Marine Corps moves toward its M&S vision, and ADS components including synthetic environments are linked together, it will be easier to confirm the validity of the results.

Establish procedures and guidelines for conduct of M&S configuration management (CM). Implementation of effective M&S CM procedures by the Marine Corps provides version control management that ensures the integrity of the computer code of each application; records the history of the M&S application by archiving the application code and documentation changes, as well as change requests and documented usage of the M&S; and provides a means by which the M&S application users and sponsors can input to the M&S enhancement process. The Marine Corps will establish effective CM procedures to preclude unauthorized modifications to the reference version of M&S applications that would invalidate previous VV&A efforts.

Implement procedures and guidelines for M&S information management. The timely and accurate dissemination of information is critical to the effective use and management of the Marine Corps M&S program. Keeping up-to-date on what is happening throughout the M&S community minimizes redundant efforts and assists in identifying candidate technologies and efforts for leveraging to meet Marine Corps M&S requirements.

Implement procedures and guidelines for M&S requirements and resource management. Effective requirements and resource management procedures are necessary to satisfy a diverse set of requirements using limited resources. Centralized review, and coordination of M&S requirements using the CDP and resource allocation through the Planning, Programming, and Budgeting System (PPBS) process will support M&S requirements and resource management. In this manner the Marine Corps can maximize the return on its investment in M&S, funding the most critical requirements in a timely manner while continuing to develop capabilities required for the future.

Leverage the efforts of other DOD components, other government agencies, industry and academia. Leveraging other M&S projects allows the Marine Corps to take advantage of the efforts underway, maximize the M&S capability it obtains for the resources expended, and reduce redundant efforts. An integral part of this leveraging effort is the identification of unique niches where the Marine Corps can support the Defense Modeling and Simulation Initiative (DMSI) or assume the development lead for a jointly sponsored effort at a relatively low cost. In this way the Marine Corps will be able to directly influence external efforts to fulfill Marine Corps needs.

Enhance technology development and transfer. By assessing the maturity and estimating the ongoing investment activities in each M&S technology area, the Marine Corps will be able to identify areas that cannot be leveraged satisfactorily and in which it needs to invest. Once these enabling technologies are identified, programs such as the Advanced Technology Demonstration (ATD) Program can be used to ensure maturation of the technologies to the point where they can transition to meet operational requirements. Identification of relevant advanced technologies, and investment in their development will ensure the technology is there when needed by the Marine Corps.

Develop a M&S Investment Plan. The Marine Corps Modeling and Simulation Investment Plan identifies funding levels and timelines required to achieve a prescribed level of capability, sets funding priorities, and addresses other funding issues. The investment plan considers user needs, current and emerging technology, the future direction of M&S, ongoing efforts, and the time lines for fielding identified technologies. Specific programs are identified for leveraging to meet Marine Corps requirements along with a discussion of the capabilities they provide and anticipated available dates. The investment plan also identifies critical elements in a technology development path, and other potential sources for obtaining technology or capabilities when required to meet Marine Corps timelines. It is the principal tool to be used in the CDP and PPBS to influence resource allocations for M&S.

Section 2.2
Integrated Technical Objectives

The Marine Corps M&S environment is based on a series of technical objectives that provide a seamless, distributed, and interoperable environment that enhances warfighting capabilities.

The classes of M&S—constructive, virtual, and live—required by the Marine Corps share several common technical objectives. These objectives support the development and implementation of an ADS environment for the Total Force. These common technical objectives are illustrated in Figure 2-2.

Move toward seamless integration of constructive, virtual, and live simulations. The development of a seamless integration of models and simulators best supports the Marine Corps' needs. Currently, Marine models and simulators exist independently from each other. They are developed for certain purposes and users, and are designed to accept only a rigid set of inputs and provide a clearly defined set of outputs. Seamless integration within a model class and between model classes will greatly increase the utility of the Marine Corps M&S program.

Establish and maintain interoperability with Joint and other Service models and simulators. M&S interoperability will allow the Marine Corps to ensure that its needs and capabilities are fully represented in the larger Defense environment. In the past, the Services tended to act without regard to the other Services. Testing, training, and analysis were performed independently to fit the needs of the individual Service, using models and simulations designed to support very specific Service needs. In the new defense M&S environment, this approach is no longer feasible nor desirable. M&S interoperability will allow MAGTF capabilities, doctrine, and structure to be accurately portrayed in other Service synthetic environments and will allow a similar representation of other Service capabilities within the Marine Corps environment.

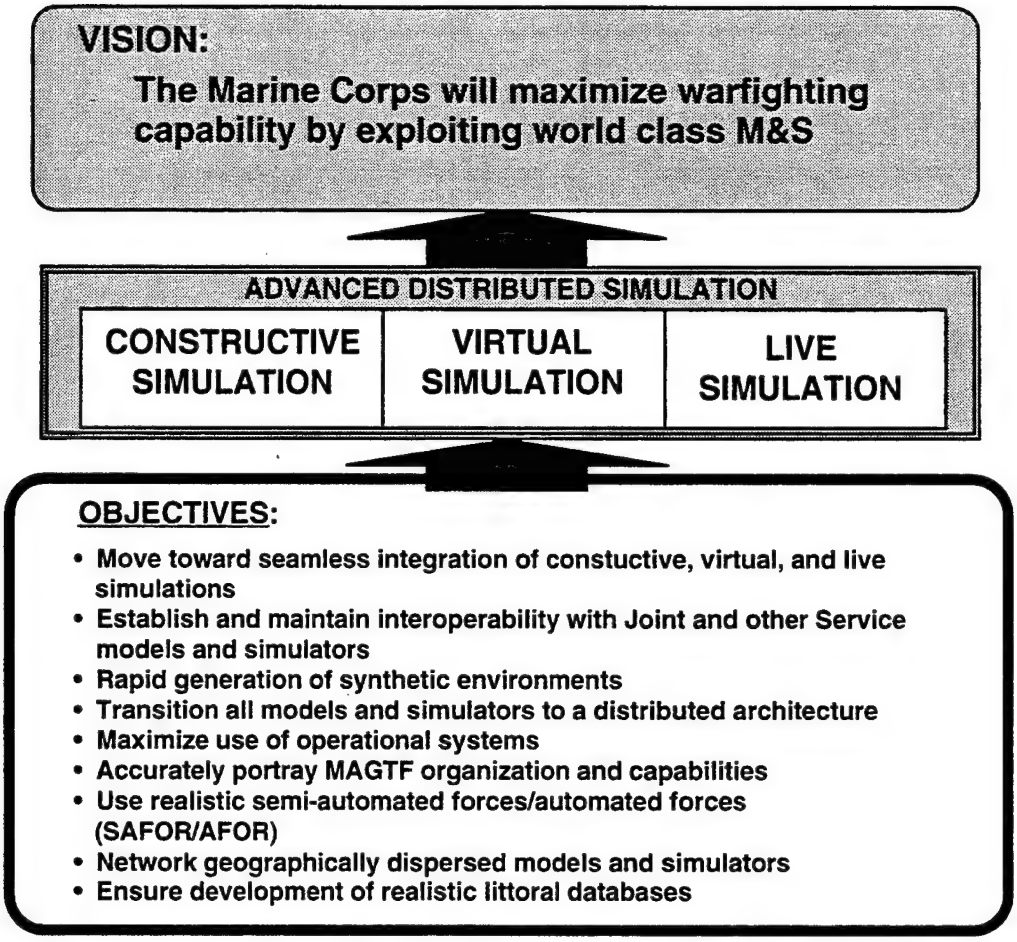

Figure 2-2. Common Technical Objectives for M&S

Rapid generation of synthetic environments. Marine Corps planners need tools that will enable them to rapidly generate synthetic environments for mission-critical applications. These synthetic environments are needed to assist in decision making, mission planning, mission preview, and mission rehearsal. The tools must be capable of taking a variety of raw inputs from National, Service, and Theater sources and, with a minimum of effort, producing accurate representations to the level of detail needed for a particular application. The capability to rapidly generate a synthetic battlefield will allow the MAGTF commander to develop and test operational and contingency plans. Once a commander has developed his plans/orders, M&S tools will be used to exercise staffs, wargame with subordinate units, and

rehearse the mission. The same systems that provide commanders after-exercise review capabilities will provide mission reconstruction to support "lessons learned" analysis. In support of this need, the Marine Corps will develop the ability to build distributed synthetic environments and related databases (terrain, doctrinal, scenario, etc.) in time to respond to actual contingencies.

Transition all models and simulators to a distributed architecture. A distributed simulation architecture based on open systems hardware and software technologies is critical to the Marine Corps' M&S program. Advanced networking technologies will tie together geographically dispersed computing resources, while open systems designs will allow these resources to easily communicate and work together. Distributed processing provides the Marine Corps with increased capabilities without increasing computer hardware acquisition. Dedicated networks must be capable of supporting the high bandwidth of information, that is inherent in M&S (particularly live instrumented test ranges), with low latency rates that will provide uninterrupted stimulus-response-stimulus interaction between the human operator and the supporting simulation systems. Since military models and simulators routinely involve classified data, this capability must also satisfy security requirements without significantly increasing bandwidth requirements and latency.

Maximize use of operational systems. The maximized use of operational systems can greatly enhance Marine Corps virtual simulation. Properly supported, the use of real world hardware makes for the most effective operational and functional training. The Marine Corps will use appended and embedded virtual simulation wherever feasible. By embedding or appending virtual simulators, Marines may train on a common synthetic battlefield regardless of equipment location (at home base, afloat, or deployed in theater). Training is enhanced by having Marines train on their own equipment, and the need for costly stand-alone simulators is reduced. Ultimately the Marine Corps will utilize its operational command, control, and communications systems and networks to support both its operational and M&S requirements. For example, the hardware suite, communications equipment, and networks comprising the Tactical Combat Operations (TCO) system will be used for operational purposes and to run distributed M&S applications that support training, as well as mission planning, preview, rehearsal, and execution. In this way the Marine Corps will be able to

merge its M&S and command, control, and communications systems reducing system and network redundancies and costs.

Accurately portray MAGTF organization and operational capabilities. Models that accurately portray the unique MAGTF task organization and warfighting capabilities, particularly maneuver warfare and operations from the sea, will fill a current void. Marine Corps M&S must realistically address the impact of logistics, C3, and intelligence assets on MAGTF operations and the commander's ability to accomplish various assigned missions. Ideally, M&S applications will possess the built-in flexibility to reflect all possible Marine Corps roles, missions, and scenarios. The Marine Corps M&S environment will provide validated representations of Marine forces and capabilities for integration into Joint simulation exercises. MAGTF representations in constructive and virtual simulations will be enhanced using operational data from live exercises.

Use realistic semi-automated forces/automated forces. SAFORs and AFORs, operating realistically, offer significant potential for augmenting friendly and threat forces in Marine Corps models and simulators. In addition, SAFOR/AFOR will facilitate the development of models that allow doctrine to be customized. This "dial-a-doctrine" capability, for both friendly and threat forces, will permit users to effectively assess concepts, to identify sound doctrine, and to conduct rapid battle planning against a variety of threat forces. Small units will train on larger battlefields with synthetic SAFORs/AFORs acting as friendlies, hostiles, and neutrals/noncombatants. Developers will test out new concepts with large sets of SAFORs/AFORs. Doctrine and weapons system developers will test their virtual developmental prototypes on a common synthetic battlefield using SAFORs/AFORs. Incorporation of realistic SAFORs and AFORs into Marine Corps virtual simulation allows the depiction of actual force doctrines and human representations. Training with SAFORs and AFORs will not completely replace actual exercises with opposing forces. Instead it allows the Total Force, from geographically dispersed locations, to better prepare for larger exercises and assists them in maintaining combat readiness between exercises.

Network geographically dispersed models and simulators. The Marine Corps will develop the capability to network geographically dispersed models and simulations. For

training needs, the Marine Corps M&S environment will provide linked exercises for geographically separated units and staffs. The Total Force, training from geographically dispersed locations, will be better prepared for actual combat. To gain maximum benefit from live simulations and to fully participate in ADS developments, instrumented ranges and sources of simulated threat signatures will be networked as well. To enhance the training of the Total Force, the Marine Corps will generate reusable synthetic environments and place these environments in a common library. The library will be networked, allowing units to "dial-up" virtual simulations applicable to their level and scope of combat or support activities. Such a capability will be built into the Marine Corps M&S infrastructure. Developers, using both virtual prototypes and actual hardware, will be able to link geographically dispersed elements of a combat system for testing and evaluation.

Ensure development of realistic littoral databases. Development of realistic representations of littoral regions are an area of particular concern for the Marine Corps. The Marine Corps will need to ensure that digitized littoral regions are developed on which we can perform virtual amphibious operations. These virtual terrains need to include more than just beaches. They should also include man-made littoral features such as oil drilling platforms, docks, and other port facilities. The environments will need to take into account the environmental effects unique to littoral areas such as surface, tides and storms, shallow water mines and obstacles, and beach gradients.

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Section 2.2.1
Technical Objectives for Constructive Simulations

Constructive models will continue to be required to meet Marine Corps M&S requirements across functional areas. They must be easily accessible and user friendly.

Constructive models play a significant role in each M&S functional area. These applications must support the full spectrum of Marine Corps requirements as well as be easy to access and use. Figure 2-3 lists specific technical objectives for constructive simulations that support the Marine Corps M&S Vision.

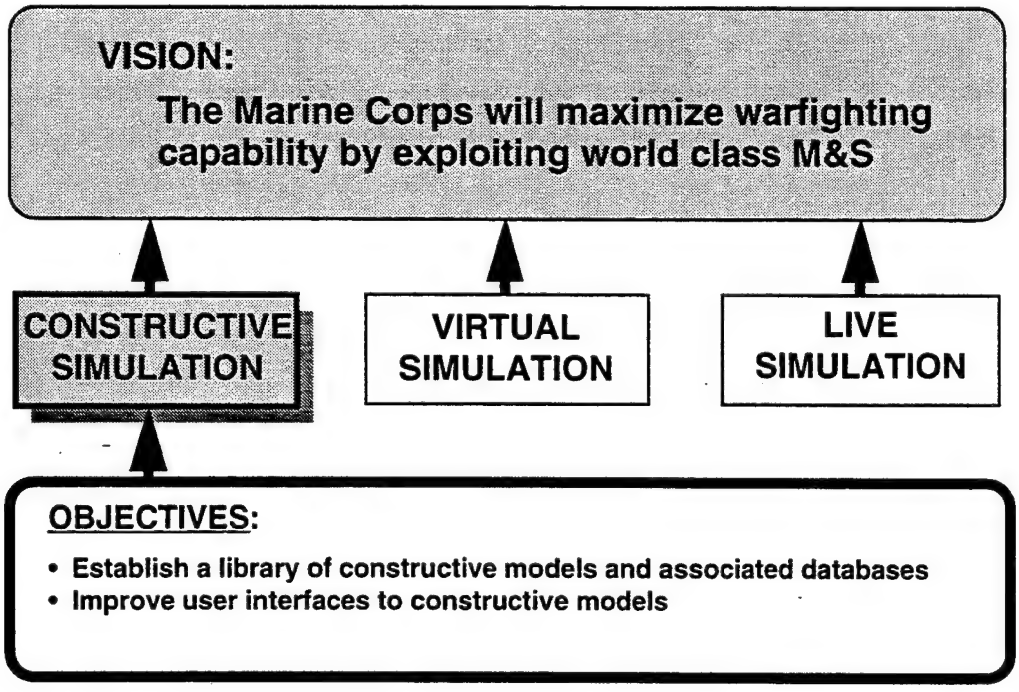

Figure 2-3. Technical Objectives for Constructive Simulations

Establish a library of constructive models and associated databases. No one model can address all issues, therefore it is important that Marine Corps users have ready access to fully interoperable validated models. These models need to range from very detailed engineering and physical models to aggregated force-on-force combat models. To support Total Force needs, fully interoperable validated models will reside as components of electronic libraries on a Global Grid. Easy access will be provided through a network interface that assures the availability of interoperable validated models to users world wide.

Improve user interfaces to constructive models. Improving the ease with which users interact with M&S applications will accommodate increasing numbers of users. Model developers and users will move from the cryptic commands of classic development languages to state-of-the-art graphical user interface (GUI) development environments. Graphics workstations with high-resolution, large screen, true-color displays will aid scenario development and wargaming with realistic visualization of terrain features using standard validated terrain databases. On-line after action report packages will allow participants to take advantage of common reference standards while evaluating individual and unit effectiveness and performance. In some cases, the capabilities provided by the graphical interface and use of artificial intelligence will provide an intuitive representation and understanding of M&S results that will no longer require interpretation by specially trained analysts.

Section 2.2.2
Technical Objectives for Virtual Simulations

The Marine Corps will make use of virtual simulation by developing modular, reconfigurable, deployable simulators and by incorporating virtual prototyping into the combat development process.

Virtual simulation technologies will be expanded to support the Marine Corps M&S environment. Pursuit of these technology objectives will allow all Marine Corps M&S users to participate individually or together on the synthetic battlefield. Figure 2-4 provides the Marine Corps technical objectives for virtual simulations.

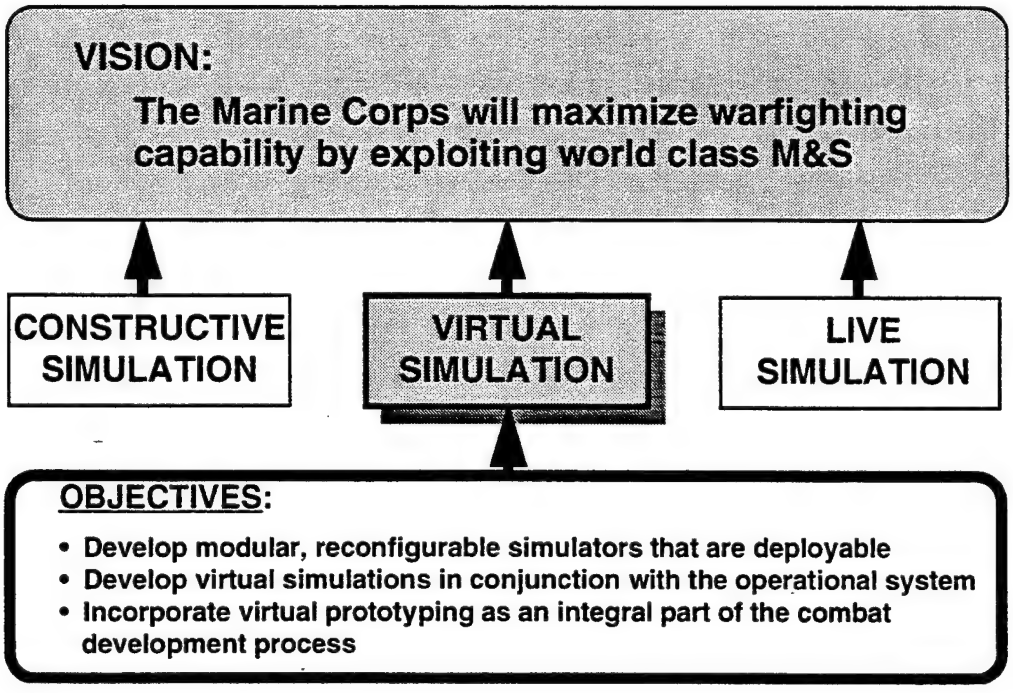

Figure 2-4. Technical Objectives for Virtual Simulations

Develop modular, reconfigurable simulators that are deployable. Modular reconfigurable simulators will support Marine Corps research and training needs. Modularity allows a single simulator type to be reconfigured to a specific vehicle or weapons system. Simulator acquisition costs are reduced because only one set of simulator hardware is needed to represent several vehicles. Overhead costs are likewise reduced at training facilities since fewer simulators and supporting assets will be required. Simulator modularity also supports research and development (R&D) allowing testing of alternate cockpit/interior layouts for proposed systems not yet built. Lastly, modularity allows the use of plug-in/plug-out technology. New simulation technology can be incrementally adapted into existing simulator frameworks as it becomes available. (Simulator users will neither have to replace entire simulators every few years, nor will they have to wait years for a single new technology to be integrated into their simulation needs.)

Develop virtual simulators in conjunction with the operational system. Virtual simulation will be an integral part of system fielding. As new combat and combat service support systems are developed, training simulators will be developed along with them. Under the new acquisition paradigm, simulations will be developed before hardware, and the Warfighter will test and train on the simulators long before the system is fielded. Virtual simulation capabilities will be appended or embedded into a system whenever possible to facilitate both training with actual equipment and deployability.

Incorporate virtual prototyping as an integral part of the combat development process. Virtual prototyping can enhance the Marine Corps Combat Development Process. Virtual developmental prototyping will allow a new weapon system to be built, tested, modified, redesigned, and reconfigured based on the results of testing in a synthetic environment. Virtual developmental prototyping has the flexibility to allow constant interaction between the designers, developers, maintainers, and warfighters throughout the entire acquisition process. Of particular importance is the ability to incorporate the user early and throughout the acquisition process.

Virtual developmental prototypes from other Services can be tested to see how they apply to the Marine Corps missions in littoral regions or to support operational maneuver from the sea

(OMFTS). New system concepts can be tested against both current and future doctrine to see if warfighting capabilities are enhanced. Virtual prototyping can be used to perform human factors analysis unique to the Marine Corps mission, and perform warrior-in-the-loop testing (in a reconfigurable virtual simulator) on a virtual system long before actual hardware is assembled.

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Section 2.2.3
Technical Objectives for Live Simulations

The Marine Corps will maximize the benefit of its live simulations by exploiting instrumented ranges and combat systems.

The Marine Corps employs live simulation in the form of live test and training exercises. To maximize the benefit of live simulations, the Marine Corps will use instrumented test and training ranges and combat systems to (1) continually observe all participants, (2) incorporate surrogate threat targets and receive simulated threat signatures from remote sites, and (3) record test and exercise events. Figure 2-5 reflects the technical objective for achieving this.

Maximize the benefit of live simulations through instrumentation. During a live simulation exercise, immediate and continual electronic feedback will keep exercise commanders and evaluators abreast of all events, even allowing the exercise to be stopped and redirected if necessary. Instrumentation will permit live simulation exercises to non-obtrusively incorporate simulated elements of threat scenarios—targets, C3I, electronic countermeasures—generated from a remote location, enhancing the environment's realism. This capability allows an instrumented test article to experience a full spectrum of environmental and threat effects without the costs and logistical burden of transporting the participants to one location. Instrumentation also permits engagements between weapon systems and targets, and assesses an engagement by immediately determining the extent of target damage. With an electronic recording of the exercise allowed by instrumentation, playback can occur as frequently as necessary during post-exercise analysis to facilitate debrief and detailed examination. This capability will enable commanders to identify unit strengths and weaknesses more readily, resulting in a more thorough assessment of their unit's readiness. This capability will also enhance the evaluation and validation of Marine Corps doctrine and tactics by permitting a more deliberate analysis. Moreover, electronic recordings of training exercises will document and support requirements development.

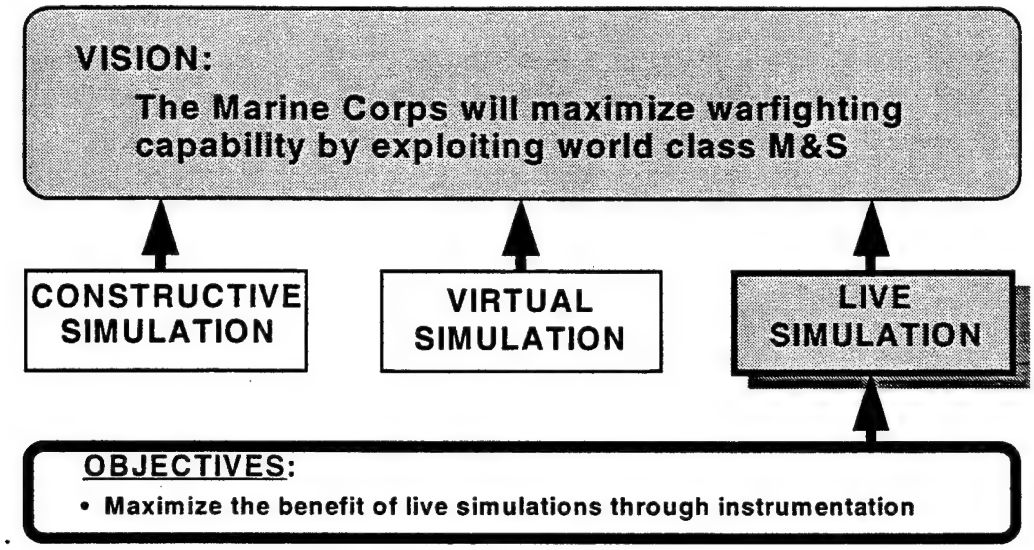

Figure 2-5. Technical Objectives for Live Simulations

Instrumented combat systems enhance tests and training exclusive of instrumented ranges. Instrumented prototypes and test articles can provide an efficient and reliable method of data collection to enhance subsequent data reduction and analysis during developmental and operational testing. During live simulation exercises and actual contingency missions, instrumented combat systems permit electronic tracking of the systems' movements, therefore facilitating command and control, and aiding in conflict reconstruction. When a training range is not available, instrumented combat systems will permit simulation of required tasks complete with realistic scenery, targets, physical weapon effects, and engagement assessments.

Instrumentation will ultimately facilitate the Marine Corps' live participation in independent and Joint ADS environments in two ways. First, it will allow the accurate inclusion of live elements in the constructive and virtual environments. Second, it will allow live participants to view simulated entities in their live environment.

Section 3
Implementation Strategy

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Section 3.1
Modeling and Simulation Policy

Marine Corps M&S policies will help it to realize its vision of maximizing warfighting capability by exploiting world class M&S.

Marine Corps M&S policies provide the guidance necessary to implement and sustain a distributed simulation environment, while maintaining the flexibility afforded by stand-alone models and simulators. These policies respond to Marine Corps M&S community needs, Marine Corps positions within the DOD M&S arena, and requirements contained in DOD Directive 5000.59. The Marine Corps will:

- Establish and maintain an M&S management framework with a single focal point
- Establish and maintain an M&S management framework which promotes the development and implementation of integrated M&S policy, procedures, processes, and guidelines
- Establish and maintain an M&S management framework that facilitates information exchange within the Marine Corps and DOD, and seeks collaborative M&S efforts with other Services and DOD agencies
- Establish and maintain an M&S management process that integrates the Marine Corps M&S Vision into the PPBS
- Identify and maintain through the Marine Corps CDP standard constructive models that support education, training, military operations, analysis, research and development, testing and evaluation, and logistics

- Establish and adhere to procedures for the acquisition of Marine Corps models and simulators that are not included as an integral part of a system acquisition

- Develop M&S standards only in areas that are not being addressed by either the Defense Information Systems Agency (DISA), the DOD Center for Standards, national, or international bodies such as the Institute of Electrical and Electronic Engineers (IEEE)

- Ensure that life cycle management of models and simulators associated with systems is the responsibility of the system development and/or maintenance organization. Assign a proponent in cases where a model or simulator is not associated with another system

- Promote the acquisition and development of models and simulators that are compatible with distributed simulation and comply with DOD M&S standards. Require a waiver from proper authority for models and simulators that are not compatible with distributed simulation or standards compliant

- Promote joint development and use of models and simulators

- Support the concept and implementation of a global network (Global Grid)

Section 3.2
Modeling and Simulation Management Framework

The Marine Corps M&S management framework supports the implementation of M&S as an integral part of the way the Marine Corps does business.

The Marine Corps M&S management framework consists of an organizational structure and management process that provides for:

- Implementing DOD M&S directives and Marine Corps policies, procedures, and guidelines
- Achieving the Marine Corps Vision for models and simulators

Marine Corps M&S Organizational Structure. To facilitate communication, integration, and decision making, the Marine Corps organizational structure parallels the DOD M&S organizational structure outlined in the DOD Directive 5000.59. The relationship between these Marine Corps M&S organizational structures is shown in Figure 3-1. The Marine Corps M&S organizational structure consists of the Executive Steering Group (ESG), the Marine Corps Modeling and Simulation Working Group (MCMSWG), and the MCMSMO. The ESG is a General Officer steering group designated by the Assistant Commandant of the Marine Corps (ACMC) as the approval authority for Marine Corps M&S requirements, plans, policies, and programs. The MCMSWG, chaired by the Head, MCMSMO supports information exchange across functional areas, participates in the development of M&S policies, procedures, processes, and guidelines, provides inputs to M&S plans, and recommends and prioritizes M&S projects for inclusion in the Program Objective Memorandum (POM). The MCMSWG uses five standing committees to interface with DOD organizations, facilitate information exchange, and support the development of policies, procedures, processes, and guidelines. The MCMSMO is the management focal-point for M&S activities within the Marine Corps (see Section 3.2.2 for MCMSMO functions).

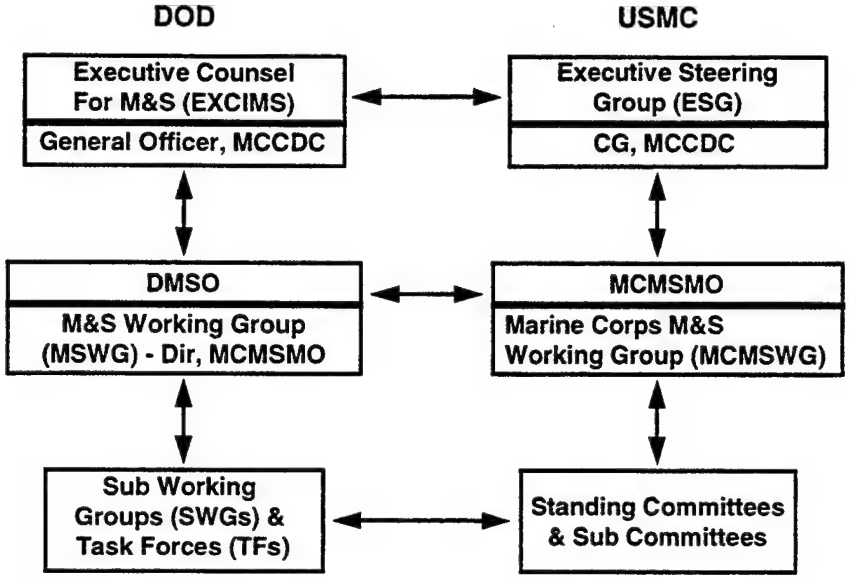

Figure 3-1. Relationship Between DOD and Marine Corps M&S Organizational Structures

Associated with the Marine Corps organizational structure are several organizations critical to Marine Corps M&S activities. These are:

- **ADS Demonstration Sites**. Two ADS demonstration sites, the MCAGCC ADS Demonstration Site located at Twentynine Palms and the proposed DMSC at Quantico (see Section 3.2.3 for a discussion of ADS demonstration sites) provide the infrastructure to demonstrate and evaluate new M&S technologies. The number of ADS sites has been limited to two to allow the Marine Corps to focus its efforts and to facilitate effective management given limited available resources.

- **Training and Education (T&E) Division, MCCDC**. T&E is responsible for the development and implementation of policy and programs for training and education of all regular and reserve Marine Corps personnel and units. They function, among other things, as the proponent for non-standard training devices and simulators,

validate training device requirements, and develop and refine the Marine Corps Ground Range Program. T&E also functions as the proponent for MTWS and provides constructive modeling support to the Fleet Marine Force (FMF), Marine Corps University (MCU), and other agencies.

- **Marine Corps Operational Test and Evaluation Activity (MCOTEA).** MCOTEA is the Marine Corps principal operational test organization. MCOTEA is an active member of the MCMSWG and provides the necessary test perspective to Marine Corps M&S policies, procedures, guidelines.

- **Marine Corps Tactical Systems Support Activity (MCTSSA), Marine Corps Systems Command (MARCORSYSCOM).** MCTSSA is responsible to MARCORSYSCOM for life-cycle management of its software. MCTSSA's integration of M&S in its testing process is a critical component in accomplishing many of the Marine Corps M&S end states.

- **Amphibious Warfare Technology Directorate (AWT), MARCORSYSCOM.** M&S related technologies are a significant element in AWT activities. AWT develops and demonstrates advanced technologies and their applicability to the Marine Corps. AWT is responsible for the management and execution of Advanced Technology Demonstrations and their eventual transition to operational programs.. AWT is a source of insights on technology which supports MCMSWG activities.

- **Command, Control, Communications, Computer, and Intelligence (C4I) Directorate, MARCORSYSCOM.** C4I is responsible for the proper transition of AWT modeling and simulation activities related to MAGTF C4I systems to the appropriate program manager offices within MARCORSYSCOM and MCTSSA. C4I also ensures the proper extension of the Global Grid into the tactical arena.

- **Marine Corps Computer and Telecommunications Activity (MCCTA), Headquarters Marine Corps (HQMC) (C4I).** MCCTA is a major activity charged with pursuing and implementing Marine Corps requirements relating to

establishing the Global Grid. Additionally, MCCTA participates in developing M&S VV&A and configuration management policies, procedures, and guidelines as a member of the MCMSWG. MCCTA also participates in establishing and enforcing data administration policies and procedures, and coordinates policies and procedures with the M&S community.

- **Wargaming and Combat Simulation Division (WCSD), MCDCC**. WCSD provides wargaming and assessment support for HQMC, the operating forces (active and reserve), and the supporting establishment including the Marine Corps Combat Development Command (MCCDC).

- **MAGTF/Expeditionary Training Center (M/ETC)**. The M/ETC mission is to strengthen and improve the coordination and integration of training opportunities among MCAGCC, MAWTS, MWTC, LFTCs (soon to be redesignated as Expeditionary Warfare Training Groups), and other Service Training Centers in a Naval Expeditionary Warfare context. M/ETC will complement training through the use of models and simulators that support mission preview and rehearsal, and battle staff training. Additionally, M/ETC will use the Global Grid to participate in Joint and CINC level exercises and increase training opportunities for geographically dispersed active and reserve MAGTF elements.

- **Proposed Littoral Warfare Training Center (LWTC) (Camp Lejeune/MCAS Cherry Point)**. This proposed LWTC would be an East Coast integrated training complex that provides for Naval/Joint Force training requirements and validation of doctrine and plans, allows for force-on-force and multiple threat scenario generation, allows for connectivitiy and continuity between the classroom and field applications of constructive, virtual, and live simulation, provides for an autonomous range sector operations capability to meet day-to-day basic and intermediate training requirements, and allows linking of infrastructures to realize a littoral warfare combat environment with instrumentation.

- **Director Marine Corps Programs (Code PDM), Naval Air Warfare Center-Training Systems Division (NAWC-TSD).** PDM provides training analysis to support Marine Corps training policy decisions; training system acquisition support; and life cycle support for fielded training systems. PDM also supports Marine Corps modeling, simulation and DIS initiatives and training systems research and development.

- **Executive Council for Modeling and Simulation (EXCIMS).** The EXCIMS was established by DOD to coordinate the management of modeling and simulation across DOD. The EXCIMS is responsible for advising and assisting the Under Secretary of Defense (Acquisition) (USD(A)) in implementing responsibilities for strengthening the use of modeling and simulation within the DOD.

- **Defense Modeling and Simulation Office (DMSO).** DMSO is responsible to the Director, Defense Research and Engineering (DDR&E) for coordinating with other government agencies, academia, and industry to develop appropriate M&S policy and to ensure that resources are being effectively used. The DMSO is responsible for the funding of a M&S infrastructure that will foster jointness by leveraging Service and Agency Programs. The Director, DMSO, chairs the M&S Working Group (MSWG) which supports the activities of the EXCIMS.

- **Joint Warfighting Center (JWFC).** The JWFC assists the Chairman, Joint Chiefs of Staff (CJCS), CINCs, and Service Chiefs in their preparation for joint warfare both in the conceptualization, development, and assessment of current and future joint doctrine; and in the accomplishment of joint training and joint exercises.

- **Joint Modeling and Simulation Executive Panel (JMSEP).** The JMSEP serves as the coordinating forum for the Joint M&S activities of the Joint Staff, unified and specified commands, Services, Defense agencies, and joint organizations responsive to the Chairman of the Joint Chiefs of Staff. This panel reviews and coordinates requirements for Joint M&S capabilities, reviews and coordinates the design and progress of new Joint M&S technologies and capabilities, and recommends and

coordinates investment plans for satisfying Joint M&S requirements for the CINCs and the Joint Staff.

Marine Corps M&S Management Process. An integral part of the management framework is a structured management process. This process supports all facets of M&S management (see Section 3.2.4) by:

- Defining and updating the Marine Corps M&S Vision
- Developing, reviewing and implementing M&S policies, procedures, processes, and guidelines
- Coordinating and integrating M&S requirements across the five functional areas
- Ensuring information interchange to support technology exploitation, leverage investments, and reduce redundancy
- Incorporating the M&S Investment Plan into the PPBS
- Overseeing the project management of Marine Corps M&S efforts receiving funding from external sources like DMSO or ARPA
- Coordinating a uniform Marine Corps position on M&S issues, and ensuring the Marine Corps presents a unified voice on M&S matters in the Joint and DOD arena

Table 3-1 provides a summary of how the Marine Corps M&S management framework responds to the requirements delineated in DOD Directive 5000.59. All dollar amounts in the table are expressed in terms of budget year dollars.

Table 3-1. Organizational Responsibilities

DOD Directive 5000.59 Component Responsibility	ESG	MCMSMO	MCMSWG
Represent their interests to the USD(A), EXCIMS, and the DMSO, as appropriate, on all pertinent matters about M&S	CG, MCCDC provides representation at USD(A) and EXCIMS	Represents Marine Corps interests at DMSO and Joint Staff	
Provide representatives to the EXCIMS, the MSWG, SWGs, and TFs, as requested by the USD(A) (DOD Directive 5000.59)	CG, MCCDC for the ESG designates a representative to EXCIMS	Head, MCMSMO represents the Marine Corps at the DMSO MSWG	Designates Marine Corps representatives to DMSO Sub WGs and TFs
Plan and provide resources, as needed, to carry out functional M&S responsibilities according to DOD Component priorities (DOD Directive 5000.59).	Approves and provides resources for M&S initiatives as part of the POM process	Participates in the Marine Corps POM development process	Recommends to the ESG a prioritized resource allocation for M&S activities (Investment Plan)
Review, coordinate, and approve DOD M&S plans, programs, policies, procedures, and DOD publications.	Approves Marine Corps inputs as required	Reviews, coordinates, and develops positions for CG, MCCDC	Assists the MCMSMO in the review of DOD M&S plans, programs, policies, procedures and DOD publications
Designate an office to serve as the single point-of-contact on all M&S matters, and for coordination with the EXCIMS and the DMSO.		Marine Corps single point of contact for M&S	
Implement an M&S management system for oversight of their own M&S activities, and for internal coordination and communication of DOD M&S issues.	Provides Executive oversight for the Marine Corps M&S program	Provides managerial oversight for the Marine Corps M&S program	Participates in the development of M&S policies, procedures, and guidelines, provide inputs to M&S plans
Provide information on M&S applications, standards, and databases managed by the DOD Component to the DOD M&S IAC.		Provides information and inputs to DOD M&S IAC	
Publish a DOD Component M&S Master and Investment Plan.	Approves Marine Corps M&S Master Plan and Investment Plan	Supports development of and manages M&S Master Plan and Investment Plan	Provides input to the M&S Master and Investment Plans. Recommends plan approval to ESG via CG, MCCDC

Table 3-1. Organizational Responsibilities (Concluded)

DOD Directive 5000.59 Component Responsibility	ESG	MCMSMO	MCMSWG
Ensure that each M&S application, standard, and database used in the DOD Component has a proponent designated to be responsible for its configuration and life cycle management	Approves sponsors/ proponents for Marine Corps M&S applications	Designates sponsors/ proponents for M&S applications with development or acquisition costs ≤ $500K	Recommends to the ESG sponsors/ proponents for Marine Corps M&S applications with estimated development or acquisition costs > $500K.
Establish procedures to explore opportunities for joint or collaborative M&S development with other DOD Components before starting development of an M&S system	Approves and prioritizes identified joint or collaborative M&S development opportunities	Conducts in-house analyses or uses the Marine Corps Study System to evaluate joint or collaborative M&S development opportunities	Reviews, prioritizes and recommends opportunities for joint or collaborative M&S development to the ESG
Establish verification, validation, and accreditation policies, procedures, and guidelines for M&S applications, standards, and databases managed by the DOD Component	Approves VV&A policies, procedures, and guidelines as an integral part of the Marine Corps M&S Master Plan	Supports development of VV&A policies, procedures, and guidelines	Recommends to the ESG the VV&A appendix to the Marine Corps Modeling and Simulation Master Plan
Ensure that M&S applications, standards, and databases are both effective and efficient. The contribution made by the use of particular M&S applications, standards, and databases during developmental and operational testing shall be documented		Reports to the ESG on the effectiveness and efficiency of M&S used during developmental and operational testing. Ensures that the contribution of M&S is documented	
Assume DOD-wide responsibility for managing a DOD common- or general-use M&S application, in response to guidance from the USD(A), when designated as a "DOD M&S Executive Agent"	Approves designated Executive Agent		Recommends Executive Agents to the ESG

Section 3.2.1
Marine Corps Modeling and Simulation Working Group

The MCMSWG provides a forum for the development, coordination, and integration of Marine Corps M&S activities.

Notional MCMSWG organizational structure. The notional MCMSWG organizational structure is a general forum comprised of voting and non-voting members and five standing committees. Figure 3-2 illustrates the notional MCMSWG organizational structure. Subcommittees can be formed by each standing committee as required to address specific issues. Since M&S touches almost every aspect of the Marine Corps, it is useful to have the widest possible participation in the MCMSWG therefore, non-voting membership is open to all interested organizations. The MCMSMO supports the MCMSWG by providing the chairman of the MCMSWG as well as administrative and technical support for working group activities.

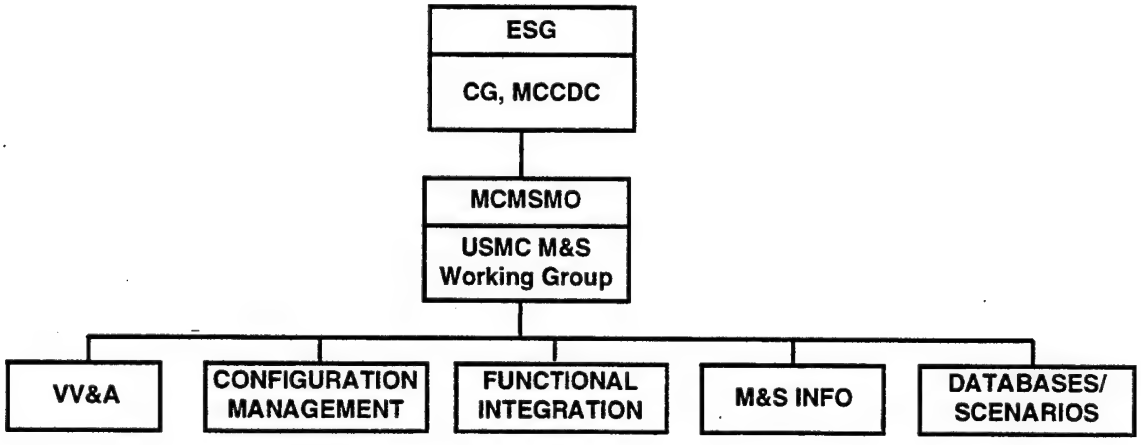

Figure 3-2. Notional MCMSWG Organizational Structure

MCMSWG voting membership. Each organization listed below identifies primary and alternate field grade or GM-13 through GM-15 voting members by name:

- MCMSMO (Chairman)
- MCCDC (WDID)
- Marine Corps Systems Command (MARCORSYSCOM)
- Marine Forces Pacific (MARFORPAC)
- Marine Forces Atlantic (MARFORLANT)
- Marine Reserve Force (MARRESFOR)
- HQMC, Manpower and Reserve Affairs (M&RA)
- HQMC, Plans, Policies, and Operations (PP&O)
- HQMC, Installations and Logistics (I&L)
- HQMC, Aviation (Avn)
- HQMC, Programs and Resources (P&R)
- HQMC, Command, Control, Communications, Computers, and Intelligence (C4I)
- HQMC Inspector General (IG)

MCMSWG standing committees. Integral to the operations of the MCMSWG are five standing committees which support the decision-making process. These committees evaluate M&S issues and present recommendations to the MCMSWG and MCMSMO for further action. The MCMSWG coordinates and establishes general membership for each standing committee. A description of responsibilities for each standing committee is as follows:

- **VV&A**— Develop and recommend to the MCMSWG uniform policies and procedures for conducting verification, validation, and accreditation of models, simulators, and their associated databases. Review, make recommendations on, and assess the results of verification plans, validation plans, accreditation plans, and data certification plans as they apply to models and simulators used by the Marine Corps. Review and assess for the Marine Corps VV&A concerns, policies, and procedures of external agencies, and represent the Marine Corps by providing subject matter expertise to VV&A organizations and/or activities of external agencies as required.

- **Configuration management**—Develop and recommend to the MCMSWG uniform policies and procedures for conducting configuration management of models, simulators, and their associated databases. These policies and procedures will generally fall into four areas:

  - Configuration documentation to define the configuration baseline
  - Configuration procedures to control changes to the configuration baseline
  - Configuration status accounting to document changes
  - Configuration audit to assess compliance with configuration descriptions

  Review and assess for the Marine Corps configuration management concerns, policies, and procedures of external agencies, and represent the Marine Corps by providing subject matter expertise to configuration management organizations and/or activities of external agencies as required.

- **Functional integration**—Monitor, identify, and report to the MCMSWG on the use of M&S in each of the five M&S functional areas. Identify potential candidates for leveraging and transitioning technologies to fulfill Marine Corps M&S requirements.

- **M&S information**—Develop and recommend to the MCMSWG uniform policies and procedures for using current and future Marine Corps networking capabilities to support M&S information and data exchange both within the Marine Corps and externally to other Services and DOD agencies. Areas of interest include Marine Corps M&S Catalog, DOD Information Analysis Center (IAC), Defense Simulation Internet (DSI), Global Grid, and Aggregate Level Simulation Protocol (ALSP).

- **Databases/scenarios**—Develop and recommend to the MCMSWG uniform policies and procedures for the standardization and portability of databases/scenarios for Marine Corps models and simulators. Work in conjunction

with the VV&A and Configuration Management Standing Committees to incorporate database/scenarios as an integral part of the VV&A and CM processes.

Each organization listed in Table 3-2 identifies a primary and alternate member for the respective standing committee.

Table 3-2. Standing Committee Members

COMMITTEE	CORE MEMBERSHIP
VV&A	Studies and Analysis Division, MCCDC (Chairman) MCMSMO HQMC (C4I) HQMC (I&L) HQMC (P&R) MARCORSYSCOM (PSA) MSTP, Training and Education Division, MCCDC
Configuration Management	HQMC (C4I) (Chairman) MCMSMO MARCORSYSCOM MSTP, Training and Education Division, MCCDC
Functional Integration	MCMSMO (Chairman) Training & Education Division, MCCDC Studies and Analysis Division, MCCDC MARCORSYSCOM MCOTEA HQMC (PP&O) HQMC (I&L) HQMC (C4I) HQMC (P&R)
M&S Information	MCMSMO (Chairman) HQMC (M&RA) HQMC C4I (MCCTA) HQMC (P&R) MARCORSYSCOM
Databases/Scenarios	MCMSMO (Chairman) Requirements Division, MCCDC Studies and Analysis Division, MCCDC HQMC C4I (MCIA) MARCORSYSCOM

MCMSWG responsibilities. The MCMSWG (working through the MCMSMO and CG, MCCDC) supports the Marine Corps M&S program by performing the following activities:

- Designates Marine Corps representatives to DMSO SWGs and TFs
- Recommends to the ESG a prioritized resource allocation for M&S activities (Investment Plan)
- Reviews DOD and other external M&S plans, programs, policies, procedures, and publications
- Participates in the development of M&S policies, procedures, and guidelines, provides inputs to M&S plans, and recommends prioritized M&S projects for inclusion in the POM
- Provides inputs to and recommends the Marine Corps Modeling and Simulation Master and Investment Plans to the ESG
- Recommends to the ESG proponents for Marine Corps M&S applications with estimated development costs greater than $500,000 (budget year dollars)
- Prioritizes and recommends joint or collaborative M&S development activities to the ESG
- Recommends to the ESG the VV&A appendix to the Marine Corps Modeling and Simulation Master Plan
- Recommends executive agents to the ESG when the Marine Corps is designated as a DOD M&S Executive Agent
- Recommends to the ESG waivers from DIS protocol compliance for M&S applications with estimated development cost greater than $500,000. Provides

waivers from DIS protocol compliance for M&S applications with an estimated development cost less than or equal to $500,000 (budget year dollars). Waiver applicability is based on technical assessments provided by the MCMSMO

- Evaluates, prioritizes, and recommends to the ESG Marine Corps M&S proposals for inclusion in the DMSO focused call process

- Assists the MCMSMO in identifying models and simulators for inclusion in the Marine Corps M&S catalog

Section 3.2.2
Marine Corps Modeling and Simulation Management Office

The MCMSMO is a dedicated service-wide, cross-functional activity, chartered to integrate, enhance and promote the use of M&S throughout the Marine Corps.

The MCMSMO is the focal point for M&S in the Marine Corps. As the focal point for M&S, the MCMSMO serves as the management and coordinating activity for all M&S related activities within the Marine Corps. In addition, the MCMSMO provides limited technical support to M&S users. The organizational structure of MCMSMO is depicted in Figure 3-3.

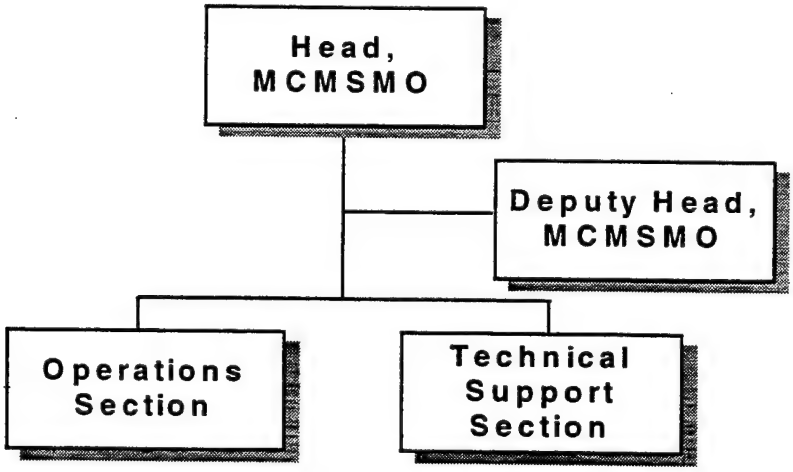

Figure 3-3. MCMSMO Organizational Structure

The MCMSMO performs the following M&S related functions for the Marine Corps:

- Head, MCMSMO chairs the MCMSWG
- Integrates Marine Corps M&S requirements into DOD and Joint forums and promotes horizontal integration of models and simulators across functional areas
- Integrates the Marine Corps M&S Vision into the PPBS by:
  - Assisting component commanders in identifying M&S concerns for inclusion in the CINCs Preparedness Assessment Report (CSPAR) and Integrated Priority List (IPL)
  - Providing a continuous interface with the Joint Staff and identifying M&S priorities for warfighting
  - Contributing to the development of the Defense Planning Guidance (DPG)
  - Contributing to the Marine Corps Master Plan (MCMP) and the Supporting Establishment Master Plan (SEMP)
  - Participating in the Mission Area Analysis (MAA) process
  - Participating in Marine Corps Study Advisory Committees as required to address M&S related issues
  - Participating in the review of all mission need statements and operational requirements documents
  - Participating in the Marine Corps POM development process

- Supporting an Office of Legislative Affairs plan that capitalizes on M&S opportunities

- Reviews, coordinates, and develops positions for CMC on DOD and other external M&S plans, programs, policies, procedures, and publications

- Supports development and manages the Marine Corps Modeling and Simulation Master Plan including requisite technical and cost assessments, and long range investment strategies

- Supports the Marine Corps ESG on all M&S matters to include policy, requirements, and prioritization of M&S projects and programs

- Supports the Marine Corps representative to the Executive Council for Modeling and Simulation (EXCIMS)

- Coordinates the efforts and participation of the Marine Corps in DMSI projects and DMSO functional working groups

- Provides the Marine Corps representative on the DMSO MSWG and provides administrative and technical support to Marine Corps representatives on DMSO sub-working groups (SWGs) and task forces (TFs)

- Provides the Marine Corps representative to the Joint Modeling and Simulation Executive Panel (JMSEP)

- Acts as the billet sponsor for Marine Corps M&S management positions external to the Marine Corps

- Supports development and implementation of M&S VV&A and configuration management policies, procedures, processes, and guidelines as required

- Coordinates and serves as the management focal point for the Marine Corps ADS demonstration sites

- Designates proponents for M&S applications with development costs less than or equal to $500,000 (budget year dollars)

- Supports and assists functional M&S users throughout the DMSI structures and processes to accurately depict Marine Corps capabilities in DOD and Joint M&S applications

- Coordinates and serves as the management focal point for the Marine Corps catalog of models and simulators

The MCMSMO also provides technical assistance to Marine Corps M&S users through in-house and FFRDC support. This support includes:

- Preparation or evaluation of technical portions of program management and technical development plans (e.g., master plans and investment strategies)

- Preparation or evaluation of M&S technical proposals

- Providing technical support to assist in defining M&S requirements

- Identification and conduct of preliminary assessments of various models and simulators to determine their applicability to Marine Corps requirements and to coordinate such assessments with appropriate functional organizations

- Providing or evaluating preliminary functional specifications for the development of proposed models, simulators, or distributed simulations

- Providing feasibility and cost analysis on M&S initiatives submitted by Marine Corps organizations, the Joint Staff, other Services, and DMSO

- Evaluation of the use and effectiveness of M&S to support Marine Corps requirements in the five functional areas

- Hosting or supporting forums on M&S issues

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Section 3.2.3
Modeling and Simulation Demonstration Sites

The Marine Corps demonstration sites for ADS provide an infrastructure in which to experiment with, demonstrate, and integrate the use of models and simulators in distributed synthetic environments.

The Marine Corps "first look" environments for M&S technologies are the ADS Demonstration Sites. These sites are located at MCAGCC, Twentynine Palms, and the proposed DMSC at Quantico. Each site provides the infrastructure necessary to demonstrate and evaluate ADS technologies capable of supporting Marine Corps M&S requirements.

The MCMSMO coordinates and serves as the management focal point for demonstration activities at the sites. ADS activities are designed to be integrated with and enhance the activities at these sites. ADS technologies are demonstrated at one or both of the sites prior to their recommendation to the ESG for general use. The MCMSMO provides a written independent evaluation on each demonstration and presents the findings to the MCMSWG and the ESG.

The ADS Demonstration Site focus at MCAGCC is to demonstrate and integrate the use of models and simulators to provide highly interactive and realistic combined arms training systems for all elements of the MAGTF, Navy components of the Naval Expeditionary Force (NEF), and other Services. The ADS Demonstration Site at MCAGCC is the primary location for:

- Experimenting, demonstrating, and integrating ADS technologies into live fire training and exercises

- Evaluating the command, control, and coordination of combined arms through the use of M&S

- Evaluating the adequacy, currency, and adaptability of doctrine to cope with ongoing changes in tactics

- Marine Corps participation in the ARPA STOW Initiative

- Experimenting with and evaluating Marine Corps SAFOR/AFOR representations

- Experimenting with and evaluating the use of high fidelity terrain representations

- Evaluating Marine Corps approaches to DIS and use of the Global Grid

The ADS Demonstration Site at the proposed DMSC at Quantico is the primary site for experimenting, demonstrating, and integrating models and simulators into an interactive decision-making environment. ADS demonstrations at this site focus on warrior-in-the-loop decision-making that enhances distributed analytical efforts in the five functional domains of: eduction, training, and military operations; analysis; research and development; test and evaluation; and production and logistics. This facility provides the Marine Corps with another "tool" where decision-maker interaction with the analyst(s) is critical and where the balanced use of many analytical tools produces the best results. The ADS Demonstration Site at the proposed DMSC is the primary location for:

- Experimenting with and evaluating advanced audio and visual displays to support senior decision makers

- Evaluating methods to access, retrieve, and display analysis data and results

- Evaluating advanced methods for applying distributed simulations to assist in analysis

- Evaluating distributed interaction with Service laboratories and remote site capabilities to support analysis and the CDP

Section 3.2.4
Modeling and Simulation Management Process

The M&S Management Process defines the building blocks used to implement the Marine Corps vision for M&S.

The M&S management process provides a structured approach for performing and coordinating the activities necessary for an effective and efficient Marine Corps M&S program. The M&S management process consists of the seven elements discussed below.

Guide M&S implementation. The MCMSMO is responsible for guiding M&S implementation. The MCMSMO works within the M&S management framework to ensure coordination is effected within the Marine Corps M&S user community. M&S implementation consists of two elements: (1) identifying and monitoring critical issues and (2) coordinating and tracking M&S activities.

Critical Marine Corps M&S issues are identified through the interaction of the MCMSMO, MCMSWG, and the user community. These issues generally encompass multiple technology domains that must be continually monitored to fully exploit their benefits. Critical M&S issues will change as M&S technologies advance. Some of the issues that will continue to be of concern in the future are:

- VV&A
- Configuration Management
- Database and Scenario Management
- Transition of Technology
- Implementation of Marine Corps M&S on a Global Grid

As these critical issues are identified, the MCMSMO will track and report periodically on the status of the issues to the MCMSWG and, as appropriate, to the ESG through CG, MCCDC.

The MCMSMO and the MCMSWG will determine whether each issue will be tracked independently by the MCMSMO or whether the MCMSMO will work in conjunction with one of the standing committees.

The second element of implementation is coordinating and tracking activities. M&S activities consist of material and non-material projects that support the use of M&S across functional areas. Material projects are projects that directly produce or result in a modeling and simulation capability. Examples of material projects include internally developed models such as the Maneuver Warfare Analytical and Research System (MWARS) and MTWS, ATD projects in virtual reality, and externally funded projects such as the SAFOR Facility at MCAGCC and DMSO focused calls. Non-material projects are projects that are important to meeting Marine Corps M&S end states, but do not directly result in or produce a modeling and simulation capability. Non-material projects include such activities as using M&S in the Marine Corps doctrine development process, integrating Marine Corps M&S requirements into Joint or other Service M&S activities, and conducting feasibility analyses of models for inclusion into the Marine Corps catalog of models and simulators.

The key to accomplishing implementation is information exchange. The MCMSMO will coordinate with proponents to track the status of material and non-material M&S activities. The MCMSMO and the MCMSWG Standing Committee on M&S Information will develop the procedures and guidelines for status reporting using Marine Corps networking capabilities.

Conduct modeling and simulation liaison. M&S is a Total Force asset. A key to the use of these assets is continuous information exchange. The MCMSMO will establish and maintain close liaison with the following Marine Corps and DOD organizations:

- Internal Marine Corps Liaisons
    - ADS Demonstration Sites
    - Littoral Warfare Training Center (LWTC)
    - MAGTF Expeditionary Training Center (M/ETC)

- External Liaisons

    - DMSO
    - ARPA
    - DISA
    - Joint Staff
    - Navy, Army and Air Force M&S organizations and activities
    - Government Agencies outside DOD
    - FFRDCs
    - National Laboratories and Academic Institutions
    - Industry

Develop, modify, and interpret M&S vision. As innovations in M&S evolve, the Marine Corps M&S Vision and objectives will change. The MCMSMO is responsible for constantly monitoring the pulse of M&S throughout DOD and ensuring that the Marine Corps M&S Vision and its associated objectives reflect the changing defense environment. The MCMSMO reviews DOD and Marine Corps planning guidance to identify potential areas for the application of M&S. Included in this review are the DPG, the CINCs' IPL, the CSPAR, the MCMP and SEMP. In conjunction with planning guidance reviews, the MCMSMO solicits inputs from the MCMSWG and M&S user community. These inputs may be a result of the Marine Corps liaison process or may be derived from inputs to the CDP such as Fleet Operation Needs Statements (FONSs) and approved need statements for doctrine, training and education, organization, mission, and support; input to the Marine Corps Lessons Learned System (MCLLS); and, Remedial Action Program (RAP) items. Once changes in vision or objectives are identified they are reviewed by the MCMSWG and MCMSMO and forwarded through CG, MCCDC to the ESG for approval.

Determine M&S capabilities, deficiencies, and needs. The MCMSMO will work in conjunction with other MCCDC organizations and the MCMSWG to develop M&S concepts and mission needs. MCMSMO will use in-house technical expertise or the Marine Corps Study System to provide feasibility analyses to support concept and need development.

Input, develop, and maintain plans. Providing recommendations to DOD and Marine Corps M&S plans is an iterative process. The MCMSMO and the MCMSWG lead this process by maintaining constant contact with other DOD organizations. The information gathering and coordination efforts of these organizations are key to ensuring that:

- DOD and Marine Corps M&S plans are complementary
- Marine Corps M&S requirements are reflected in DOD, Joint, and Navy M&S plans and planning
- Marine Corps M&S requirements are reflected in the MCMP and SEMP
- The Marine Corps M&S Master Plan is updated as required
- The Marine Corps M&S Investment Plan is updated as required

Participate in the POM process and in National Guard and Reserve Equipment Appropriation (NGREA) input development. As a critical M&S issue, resources must be allocated to M&S projects necessary to implement the Marine Corps Vision. The MCMSMO participates in the POM development process at MCCDC, MARCORSYSCOM, and HQMC (I&L).

The NGREA provides for Congressional support of MARRESFOR apart from funding authorized in the POM. MARRESFOR and HQMC (M&RA) develop M&S initiatives to support requirements for funding through the use of NGREA. The MCMSMO assists MARRESFOR by coordinating M&S initiatives for NGREA funding.

Provide integration and oversight of M&S projects. The MCMSMO performs managerial functions, integrates M&S efforts, and provides management oversight for M&S projects. The MCMSMO integrates internal M&S activities to ensure that the project supports one or more M&S end states defined in the Master Plan, that each M&S project is applied across the

five functional areas (as appropriate), and that current technologies are leveraged to the maximum extent possible. The MCMSMO also provides managerial oversight for internally funded M&S projects. This oversight function ensures that the MCMSMO, MCMSWG, and the ESG (through CG, MCCDC) are aware of the current status of each M&S project. The MCMSMO also provides integration and oversight functions for externally funded M&S projects identical to those for internally funded projects.

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Section 3.3
Investment Strategy

The Marine Corps investment strategy identifies the technology areas that the Marine Corps needs to invest in and provides generalized guidance concerning funding of efforts within these areas.

The Marine Corps M&S investment strategy is simple and straight forward. Marine Corps investment in M&S technologies will focus on the areas identified as enabling technologies and will be based upon the following three principles:

- Maximum leveraging of M&S efforts sponsored by the other Services, other DOD and government agencies, industry, and academia to meet Marine Corps requirements

- Obtaining non-existing M&S capabilities through cooperative development efforts whenever possible

- Embarking on M&S development efforts solely involving the Marine Corps only when they cannot be obtained through leveraging or cooperative development

Definitive guidance for implementing this strategy will be published as a separate Marine Corps Modeling and Simulation Investment Plan. This plan will include other significant costs associated with implementing a Marine Corps ADS environment. These costs include such things as contractor support, hardware and software procurement, and maintenance and operational support.

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Section 3.4
Enabling Technologies Supporting M&S End States

Each of the defined M&S end states will require a set of mature technologies.

In order to reach any particular M&S end state, a set of supporting technologies will need to be developed. Appendix A assesses the status of M&S technologies in general. This section, however, presents a list of the end states and a summary of the specific technologies required to meet those end states. Note that there are other elements, not covered here, required to implement the end states. These include development of policies, training for the use of the systems, supporting supplies, and administrative and maintenance personnel. The costs associated with these other elements are not included in the development costs of the enabling technologies discussed below, but will be discussed in the Marine Corps Modeling and Simulation Investment Plan.

- **Exercise any size Total Force MAGTF as part of a combined or joint force from home bases, aboard ship, or forward deployed through the seamless integration of live, virtual, and constructive simulations**:

  - A very high capacity network, with transfer rates higher than 155 megabits per second, that will include land, sea, and air connectivity (Global Grid)
  - ADS capable, interoperable models that correctly portray MAGTF capabilities
  - ADS capable, interoperable simulators
  - Instrumented training ranges, weapons platforms and systems
  - High-resolution three dimensional displays

- **Conduct mission planning in a distributed environment:**

  - A very high capacity network, with transfer rates higher than 155 megabits per second, that will include land, sea, and air connectivity (Global Grid)

- Construction tools capable of rapidly building realistic synthetic environments (including littoral environments)
- High-speed, light-weight, high-resolution three dimensional displays

- **Conduct mission preview and rehearsal on land or at sea at all levels, from the individual Marine to MEF within 48 hours of tasking:**

  - Construction tools capable of rapidly building realistic synthetic environments (including littoral environments)
  - A very high capacity network, with transfer rates higher than 155 megabits per second, that will include land, sea, and air connectivity (Global Grid);
  - ADS capable, interoperable models that correctly portray MAGTF capabilities
  - ADS capable, interoperable simulators
  - Integrated with real world systems
  - High-speed, light-weight, high-resolution three dimensional displays
  - SAFOR models capable of providing the numbers of friendly and enemy forces

- **Validate Marine Corps requirements and doctrine using M&S as a primary tool:**

  - SAFOR models capable of providing the numbers of friendly and enemy forces necessary for testing and analysis at any echelon
  - Constructive models (both stand-alone and ADS-capable) that correctly portray MAGTF capabilities
  - Simulators (both stand-alone and ADS-capable)

- **Participate in the fundamental improvement of the acquisition process by simulating before "we buy, build, or fight":**

  - Engineering design models and simulations, capable of being linked into an ADS synthetic environment when and where appropriate

- A realistic synthetic environment upon which a virtual prototype can be tested
- A set of reconfigurable simulators, representing different types of platforms (armored, helicopter, fixed-wing aviation, truck, etc.), that support a family of weapons or systems

- **Merge M&S and command, control, and communications systems:**

  - A very high capacity network, with transfer rates higher than 155 megabits per second, that will include land, sea, and air connectivity (Global Grid)
  - Common hardware resources (computers, displays, communications networks, information storage, etc.) shared between simulation and operational activities

- **Support every major weapon system in the Marine Corps with a simulator that can be networked into a common synthetic environment:**

  - A set of reconfigurable simulators, representing different types of platforms (armored, helicopter, fixed-wing aviation, truck, etc.), that support the family of weapons or systems
  - Light-weight, high-capacity simulator equipment either physically appended onto a platform or embedded into the platform's existing electronic systems
  - A database of models that portray the operations of each system
  - Instrument real systems and tie in through the global grid

- **Use M&S as a primary decision support tool:**

  - Interoperable over the Global Grid where required
  - Models, both stand-alone and ADS-capable/interoperable, that correctly portray MAGTF capabilities
  - Simulators, both stand-alone and ADS capable/interoperable
  - A very high capacity network, with transfer rates higher than 155 megabits per second, that will include land, sea, and air connectivity (Global Grid)
  - Instrumented training ranges, weapons platforms and systems

- High-resolution three dimensional displays
- Construction tools capable of rapidly building realistic synthetic environments (including littoral environments)
- SAFOR models capable of providing the numbers of friendly and enemy forces necessary for testing and analysis at any echelon
- Engineering design models and simulations, capable of being linked into an ADS synthetic environment when and where appropriate
- A realistic synthetic environment upon which a virtual prototype can be tested
- A set of reconfigurable simulators, representing different types of platforms (armored, helicopter, fixed-wing aviation, truck, etc.), that support a family of weapons or systems
- Common hardware resources (computers, displays, communications networks, information storage, etc.) shared between simulation and operational activities
- Light-weight, high-capacity simulator equipment either physically appended onto a platform or embedded into the platform's existing electronic systems
- A database of models that portray the operations of each system

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Appendix A
Technology Assessment

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Section A.1
Enabling Technologies Assessment

The Marine Corps ADS environment will build on a series of enabling technologies that will enhance the Marine Corps warfighting capabilities.

Marine Corps modeling and simulation (M&S) efforts are built upon a series of enabling technology layers, as shown in Figure A-1. Each layer consists of both hardware (which tends to be commercially driven) and software technologies and simulation architectures (which tend to be Department of Defense [DOD] driven). At the base of the Marine Corps

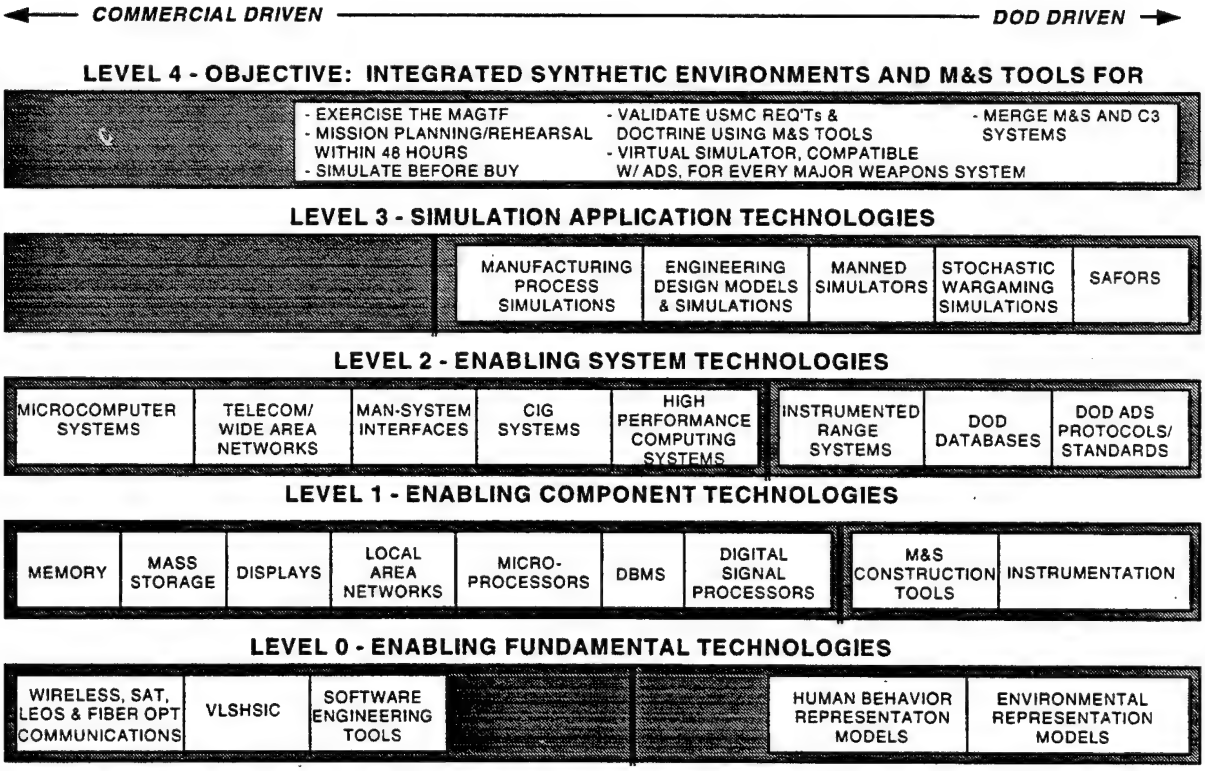

Figure A-1. M&S Enabling Technology Hierarchy

Advance Distributed Simulation (ADS) environment are enabling fundamental technologies. These include commercially driven base technologies such as fiber optics, integrated circuit developments, and software engineering technologies and tools, and DOD driven efforts like platform, human behavior, and environmental representation models. These fundamental technologies combine to form the next layer, component technologies. Component technologies consist of integrated hardware such as display systems, microprocessors, and storage/memory systems, and integrated software such as database management systems (DBMS) and M&S development tools. Component technologies are combined into system technologies such as microcomputer systems, human-computer interfaces, instrumented ranges, information databases, and protocols. These first three enabling technology levels combine to form specific simulation application technologies, which generally fall into the constructive, virtual, and live categories and the areas (such as SAFORs and environmental databases) common to all of them. The objective is the last level—an integrated synthetic environment with a common set of support tools for prototyping, program planning, training, mission rehearsal, etc. This M&S enabling technology hierarchy provides the building blocks for the Marine Corps ADS environment. The following subsections divide the enabling technologies into two categories: those that are supported by hardware technologies, and those supported by software technologies.

Section A.1.1
Enabling Hardware Technology

The Marine Corps will use commercially available hardware technologies as the technology support for its ADS environment.

Much of the hardware technology for Marine Corps M&S will be commercial off-the-shelf (COTS) and government off-the-shelf (GOTS). Figure A-2 illustrates the specific enabling hardware technologies that support general M&S needs.

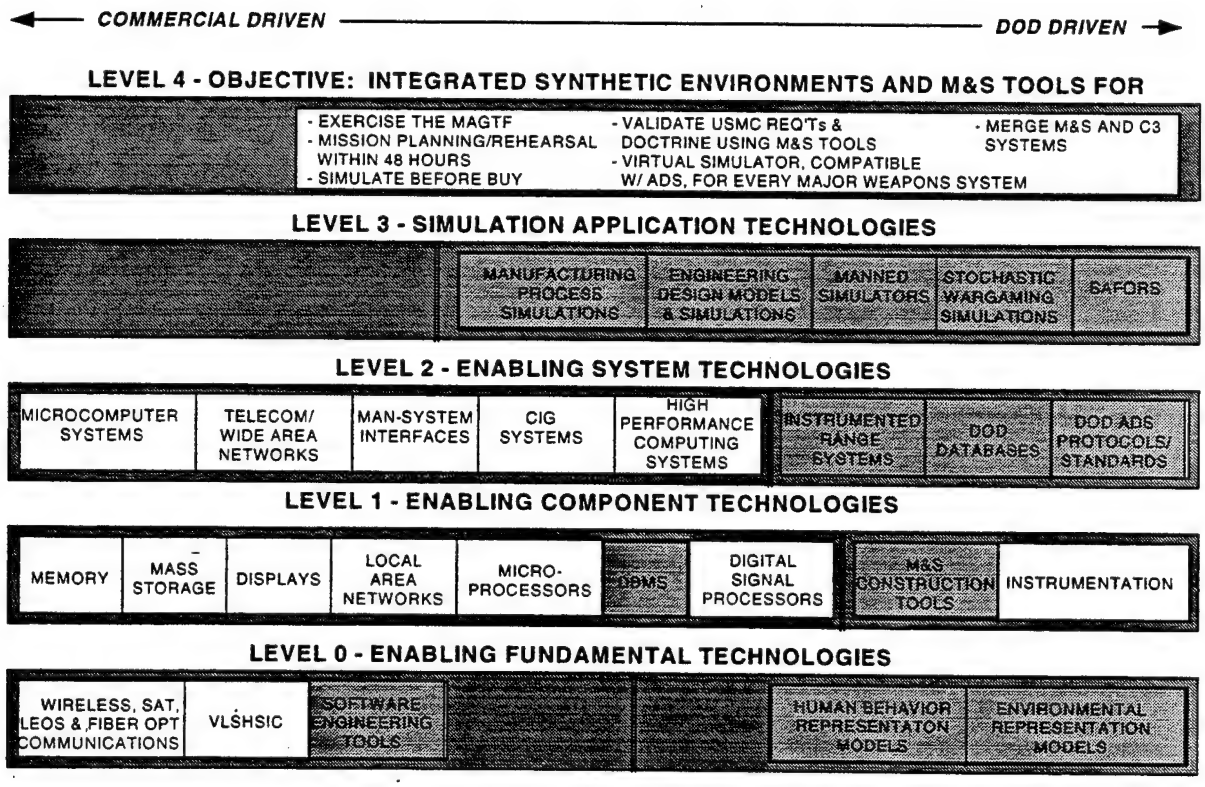

Figure A-2. Enabling Hardware Technologies

Display technology/computer image generation systems. Display technology is among the most mature of M&S technologies. Planned commercial developments in this area will be sufficient for Marine Corps needs. Display technologies are generally classified into two basic categories: active (light-emitting) displays such as cathode ray tubes (CRTs), large screen video projectors, passive devices such as liquid crystal displays (LCDs), and electrophoretic displays. CRTs have provided the overwhelming majority of displays for M&S to date, but have reached a level of maturity that is not likely to advance. However, the commercial community is making great strides in lightweight flat panel display technologies. These advances will fit in well with Marine Corps requirements in the command and control area. Large, color LCDs with somewhat lower resolution than similarly sized CRTs are available commercially. Head/Helmet mounted displays (HMDs) are being developed for both commercial and military communities (as a replacement/enhancement to traditional heads-up displays in cockpits). Currently, there is limited production of wide-field-of-view binocular HMDs, and laboratory versions of color HMDs are in development.

Displays provide the front end for integrated computer image generation (CIG) systems. CIG provides visual cues at speeds needed (usually in real-time) for human operators to perform their required tasks. CIG performance is a function of a number of factors, including screen resolution and polygon and pixel throughput. Current state-of-the-art CIGs can display 1 million polygons per second, refresh the screen at a rate of 100 million pixels per second, and have a resolution of 2048 x 2048 pixels or more. By 2000 it is expected that this will increase to 12 million polygons/sec and a refresh rate of 3 billion pixels/sec. Such capacity should more than meet Marine Corps requirements for crew-served weapon and aircraft simulators. However, it is currently unclear as to whether this technology will provide fully adequate visuals to the individual combatant.

The trend in graphics is toward improved cost performance and higher resolution and fidelity. Current standards for very high fidelity, dynamic synthetic environment representations are currently difficult to implement and restricts the developer. The more widely used standards for lower-end 3-D display, 2-D graphics, and graphical user interfaces (GUIs) are more effective. The DMSI lists several initiatives that should be pursued in order to support DOD M&S graphics needs. These are:

- Strengthened developments in rendering engines
- Display buffers and image transfer mechanisms to create better 3-D displays
- Improved graphic rendering algorithms used on parallel computers
- Support for the development of rigorous graphics standards

Computing hardware. ADS will require computing hardware capable of processing large amounts of data very rapidly. ADS will use the whole range of computing platforms, from microcomputers to super computers. While current systems are not capable of fully implementing the ADS vision, it appears that current technology growth trends will continue and required levels of computing power will be available. The processing power, speed, memory capacity, and functional capabilities of computer systems will continue to increase while their relative costs will continue to decrease. This trend is due largely to pressures from the commercial sector. Perhaps the keystone of new computer hardware for ADS is the development of very powerful, inexpensive, workstation-class machines. The availability of large numbers of such machines will make possible many of the visions for virtual simulations (especially distributed ones). In general, while developments are proceeding apace, the DMSI notes several initiatives that should be pursued in order to fully realize ADS. Computing hardware must be capable of supporting applications being executed in real-time (with an emphasis of real-time execution across geographically distributed systems). Massively parallel processing architectures of some high level systems will need concurrent efforts in parallel algorithm development. Careful consideration must be given to interoperability between many diverse systems (especially COTS). While interoperability is an issue of commercial interest, its importance to internetted simulation will require that the Marine Corps be at least a player in the arena in order to ensure that its needs are met. Because DOD has been the prime user of geographically distributed, real-time simulation, it will continue to be a main developer of this technology area and the Marine Corps must participate to ensure its requirements are met.

Memory/storage technology. Silicon-based Dynamic Random Access Memory (DRAM) chips now constitute the vast majority of the computer memory market since they are used in almost all computer system products ranging from personal computers to mainframes. The Marine Corps ADS environment will need vast amounts of high-speed DRAM to support the

data needed to create synthetic environments. Since the introduction of DRAMs, their storage capacities have been quadrupling every three years. It appears that the historical trends will continue for another three generations, with 16 megabit DRAMs available in 1993, 64 megabit DRAMs in 1996, and 256 megabit DRAMs in 1999. Assuming current pricing trends will also continue, the unit cost of storage could be as low as $0.08 per megabit by the year 2000. The approach to 2010 will see the development of an entirely new form of memory based on electro-optical and optical technologies. Such memories provide greater speeds, capacities, and throughput, and will more seamlessly integrate with fiber optic-based networks, thus greatly increasing the power and capabilities of the developing simulation internets. It seems likely that these memory technologies will become available as current silicon-based DRAM technologies reach a mature developmental plateau.

Mass storage refers to any device that can store large amounts of data and retrieve it at some later time. It is usually categorized in terms of being either the faster on-line (usually magnetic or optical hard drives for immediate retrieval of data) or the slower off-line (magnetic tapes or removable drive media for data backup and archiving) variety. The creation of detailed synthetic environments will require large amounts of both types of storage. Magnetic disk technology is by far the most advanced and predominant mass storage technology employed today. Optical disks record data by using a laser to change the reflective properties of an optical media. They have high storage capabilities but are slower than magnetic disk drives. Magneto-Optical recording is a hybrid technology that attempts to combine the best features of magnetic and optical recording. The consensus today is that magnetic storage has not yet approached its technical limits, and that magnetic hard drives will still be the primary mass storage technology in the year 2000. If current trends continue, single platter 5.25 inch drives with capacities of 3.8 gigabytes should be available by or before the year 2000. Optical storage technology is also supposed to advance, although to move out of the backup/archival role it now plays, its speed performance will need to be increased. High-capacity removable media devices will be required by the Marine Corps if we are to be able to take our synthetic environments with us to the battlefield.

It is difficult to say with precision what the memory and storage requirements of any specific ADS exercise will be. Each exercise will have different requirements and these will fluctuate

over the course of the exercise. However, if the trends noted above continue, Marine Corps M&S users (even down to reservists participating from their homes) should have enough capacity to support their node's requirements within all M&S exercises and activities envisioned from now into the next six to ten years.

Human interface technology. Human-computer interfaces encompass a wide variety of technologies that enable humans to exchange information with computer systems. They range from basic technologies such as alphanumeric keyboards to sophisticated speech recognition and virtual reality systems. Machine-to-human information transfer technologies may be classified as visual, auditory, and tactual. Human-to-machine information transfer technologies may be classified as physical (controls and eye, head, and hand-tracking devices) and non-physical (speech recognition). Because of the diversity of the technologies in this category, it is difficult to define common performance measures. Position sensing technology is beginning to mature, but angle measurement systems (for gesture/movement interpretation) remain primitive. Tactile stimulation/force feedback mechanisms are still at the laboratory level, and while industry and academic interest has recently begun to increase, overall funding is low and no practical solutions are visible for the near term.

In general, the technologies in this category are being driven heavily by commercial (especially consumer) needs, and should fully meet Marine Corps ADS requirements. Major exceptions include: machine language comprehension (vs. speech recognition) which is tied in with advances in artificial intelligence and is likely to remain a problem largely unresolved past the year 2000; and the angle measurement and tactile stimulation/force feedback technologies (discussed above) that are required to fully support the individual combatant in virtual simulations.

Networking technology. A key element in realizing the ADS vision of internetted virtual simulations is the network technology used to link the simulators together. Networks can be divided into three general classes, each with their own hardware constraints and considerations. Local Area Networks (LANs) are used to link virtual simulators that are within miles of each other and are often in the same building. Wide Area Networks (WANs) are used either to link geographically separated simulators or as backbones to link

geographically separated LANs. Related to WAN technologies are those used for purely remote connection using satellite technology, fiber optic communications, or other wireless means. Wireless communications is a critical technology for linking in simulators being carried on board ships or forward deployed, and may be the only means of linking live equipment into the virtual battlefield. Integrated services data network (ISDN) and asynchronous transfer mode (ATM) technology need to be investigated because they can provide cost-effective, on-demand access to a wide range of data transmission services configured by the user such as a T1 circuit for the duration of an exercise.

To fully support the ADS vision for virtual simulation will require networks that can carry megabits of data per second. Component technologies for such networks include ATM switching, synchronous optical networks (SONET), and spread-spectrum technologies for wireless communications. Universal protocols supporting communications networking are being developed, and encryption technology is keeping up with developments (although special attention must be paid to the differing security levels required by distributed virtual simulations representing different elements). Currently, data transfer rates of 155 million bits per second can be achieved over fiber optic lines. It is expected that 2.4 gigabits per second will be demonstrated over trunk lines in the near future. Commercial developments of SONET and ATM technologies for gigabits per second transfer rates may be available by 1996/1997. By the year 2000, optical switching technologies (in the form of photonic switches) will replace existing electronic switches (a primary bottleneck in fiber optic based systems), enabling extremely high speed fiber optic networks. The Marine Corps will need configurable networks capable of quickly transmitting large amounts of data among geographically distributed sites. Current networks such as the DSI cannot meet Marine requirements for the synthetic battlefield. Low earth orbiting satellites (LEOS) need to be investigated for use in ship-to-shore links and connections for remote sites.

As with memory/storage requirements, determining specific network requirements for ADS exercises in general is difficult and will vary for each exercise. However, some requirements have been developed for a range of specific exercises. These figures can be used as a basis for roughly estimating the overall networking needs of ADS exercises. For example, the Draft *Defense Simulation Internet Operational Assessment Report* (Logicon, 22 January

1993) expects for a notional exercise involving 20 aircraft, 24 ships, and three tactical data links that the bits per second traffic load to a DSI-style net will be 389,318 (best case), 2,013,032 (expected case), or 3,095,508 (worst case). For a notional exercise involving 200 tanks, 100 aircraft, 5 tactical voice links, and 3 tactical data links, the bits-per-second traffic loads are estimated at 833,060 (best case), 3,998,996 (expected case), or 6,109,620 (worst case). Such loads exceed the capabilities of today's T-1 based DSI, but developments in the near- to mid-range (especially adoption of T-3 lines at 45 megabits per second and ATM) and networks supporting these rates will satisfy developing Marine Corps requirements.

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Section A.1.2
Enabling Software Technology

The Marine Corps will leverage many of its software needs. However, it must be prepared to develop ADS application for Marine Corps unique requirements.

Much of the enabling software technology needed for Marine Corps M&S is being developed by DOD and industry. While the Marine Corps will be able to use this software, it will still need to develop some specific technologies for its own unique needs. Enabling M&S software technology areas include environmental representations, Computer Generated Forces (CGFs), and software engineering tools. The specific software technologies supporting these areas are represented in Figure A-3.

Environmental representation. The set of software technologies used to replicate the real world for users of simulations are called environmental representations. These technologies are divided into general categories:

- Databases of normally static features, such as:
  - Terrain altitudes and features
  - Vegetation
  - Roads
  - Bridges
  - Buildings
- Environmental models of more active, less permanent elements of the environment such as:
  - Seasonal terrain effects (snow, mud, seasonal changes in vegetation)

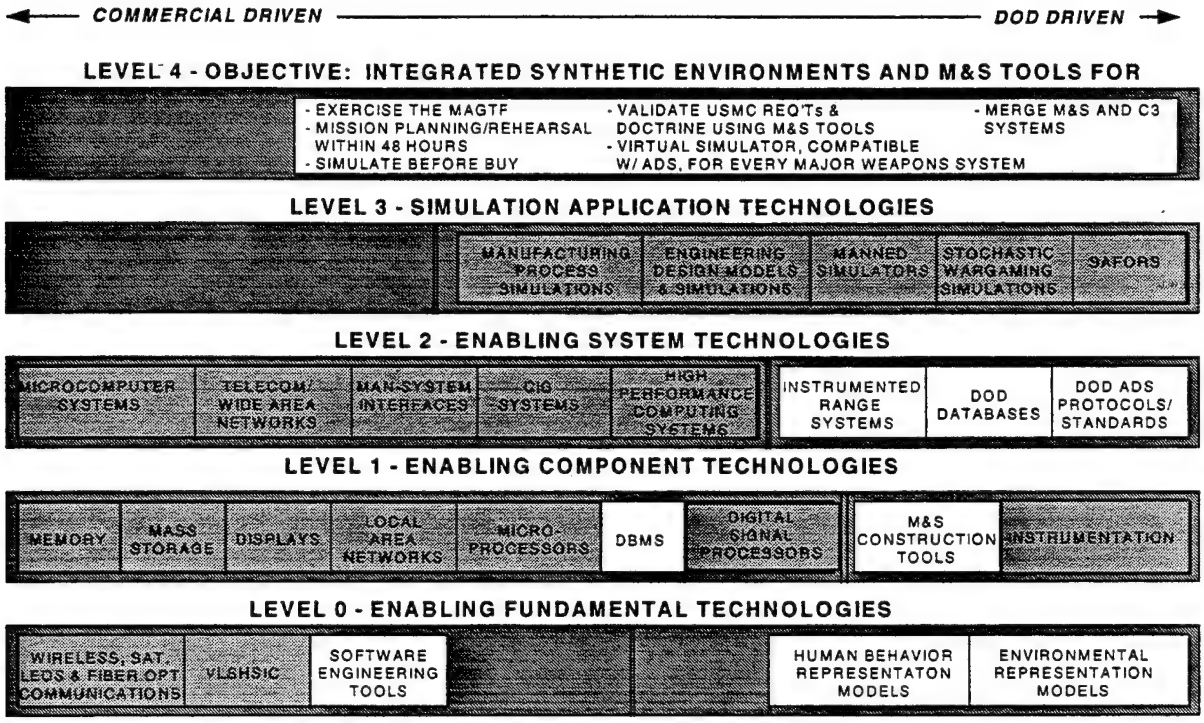

Figure A-3. Enabling Software Technologies

- Oceanic environments
- Atmospheric environments
- Electromagnetic environments
- Obscuration models
- Models of the interactions between different environments (such as shore-sea tide and storm models)

Environmental representation will also be required to support analysis. These must be very accurate, realistic environmental representations that ensure analysis results accurately correlate with those of the real world. Environmental representations for training or mission planning and rehearsal purposes require models that accurately portray the visual and motion representations of elements in the environment.

Current technology supports the modeling and rendering of integrated terrain models. The mid-term (four to nine years) will see an extension of this capability to the linking of accurate dynamic environmental models. The far term (sometime in the next decade) will see the realization of a global hierarchy of interoperable terrain and environmental models. While these goals are achievable, the development community is not yet sufficiently well organized to leverage technology developments in other areas.

Another key constraint has been the lack of standardization between existing data sets and models. The Air Force's Project 2851 is attempting to define a standard library of terrain data for DOD simulations, but a complete infrastructure for database and model storage, standardization, and transmission is still needed. The current set of DIS protocols and the DSI network as it now exists probably can not provide needed services for a full realization of internetted virtual simulations.

Computer generated forces (CGFs). CGFs include the emulation of humans by computers, from detailed physical and behavioral modeling of individuals, to the aggregated doctrinal and force modeling of unit SAFORs and AFORs. The capability to develop physical models emulating individuals, including such details as internal organs, performance capabilities/limits, and biomechanical activities currently exists, but the actual activities either have not yet begun or have not been integrated. While the modeling activities exist, especially in academia and elsewhere in the Government, in many of these individual categories, DOD may need to support their integration. Modeling of weapons effects on individual humans (especially advanced/new weapons technologies) will need to be DOD driven.

The algorithmic emulation of human behavior is the basis for providing realistic computer-controlled forces necessary for large simulations, areas of modeling include: cognitive processes; 'soft factors' such as fear, fatigue, morale, will to fight, and cultural tendencies; command decision making; and operational issues such as planning, tactics, and doctrine. Advances in this area are required to create distributed forces for joint task force operations. Today the state of the art in SAFORs is still relatively primitive in terms of the level of intelligence they replicate. Even so, SAFORs have already proven useful for training and

development activities. The DMSI identified four general trends in what it terms "behavioral representation": improved formal methods and tools; enhanced representation of automated forces (i.e., manifesting human judgment); improved individual training simulations; and the emergence of variable resolution simulations with explanation (feedback) capabilities. Critical developments will include vertical integration between the SAFORs of different echelons as well as a more complete seamless integration horizontally between SAFORs and actual human elements in the same echelon. The key challenge is developing algorithms that realistically replicate behavior (both the independent actions and interdependent reactions between SAFORs and humans). In general current developments are insufficient to support advanced virtual simulation. The low level of funding currently being provided primarily by ARPA will need to be increased dramatically in order to realize the benefits of this technology.

Software engineering tools. Software engineering tools are a support technology applied across the entire range of M&S activities. Commercial activities have focused on generalized computer aided software engineering (CASE) tools. These tools are still in their infancy, but the costs behind software development are pushing commercial development of better and more versatile CASE tools. General software engineering trends in M&S include a move from stand-alone to distributed/interoperable systems, enhanced reuse and extensibility, and better defined architectures and standards (e.g., enhanced capability maturity). Software engineering tools specific to M&S, especially virtual simulation, are currently very limited in number and scope. Particularly weak are tools to support the rapid development of virtual environments (especially the terrain databases) to support rapid scenario development and to aid in building/developing accurately portrayed SAFORs. Investment in these complex and specific tools will largely fall on DOD. To date some work has been performed by the RAND Corporation under ARPA and Army sponsorship.

Section A.2
Technology Assessment: Constructive Simulations

DOD constructive M&S technology is focused on use of object-oriented design and programming, open systems architecture, distributed processing and more realistic portrayal of all aspects of combat.

The sets of constructive models currently under development within the DOD are characterized by the use of Object-oriented Design (OOD), Object-oriented Programming (OOP) and extensive GUIs using an Open Systems Architecture and designed to run in a distributive mode. DOD is applying this approach to promote sharing of constructive models, simulations, databases, and scenarios. Use of an object-oriented environment provides a wide range of extensible and reusable code objects. Applications developed using an open systems architecture are machine independent and therefore portable to any variety of existing and planned computer systems. Distributed storage and processing means applications, data, and computed results can be shared on a network, and that application execution load can be shared across the systems on the network. Applications software and associated databases do not have to reside in a single location. Anyone with proper access to the network will have access to the applications and the data they need. The specific technologies that support constructive simulations are denoted in Figure A-4.

Model Architecture. The other Services are moving toward a common architecture for constructive simulations. These architectures will make use of object-oriented software and open systems hardware technologies. An object-oriented program consists of a collection of self-contained program units that communicate with each other by sending messages. These self-contained units or objects represent real-world entities. In an object-oriented model, these objects are organized hierarchically so that the behaviors and characteristics of higher level objects can be inherited and used by lower level objects. This provides a powerful construct for software development in that objects and object hierarchies can be reused

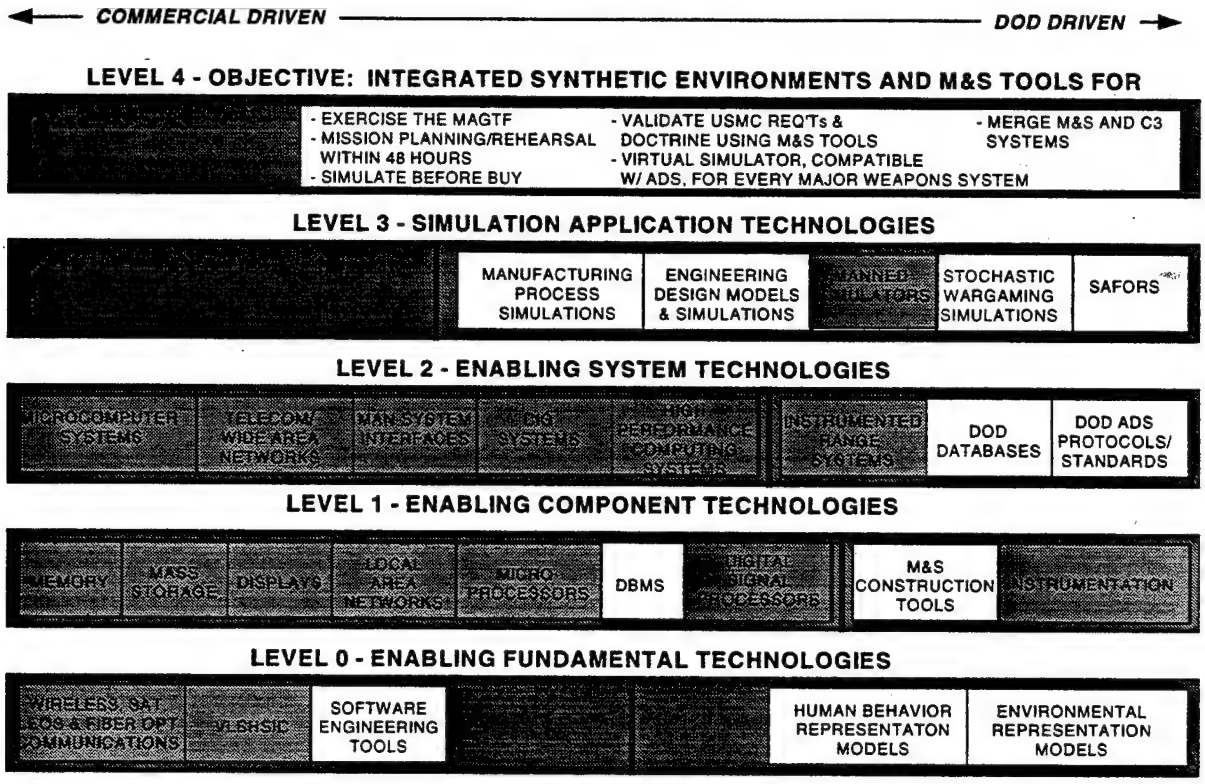

Figure A-4. Technologies Supporting Constructive Simulations

thereby reducing costs in subsequent software development efforts. Open systems architecture facilitates migration of the software applications to other computer systems.

Interoperability. Interoperability between existing constructive models is currently being provided by ALSP. This technology provides a protocol-based simulation linkage architecture to allow interaction of dissimilar constructive simulations on a common battlefield. This means that existing service proprietary simulations can jointly play in the same wargame. Air, ground, and naval operations are currently played in the ALSP Confederation, with each Service responsible for modeling of its own mission area. The Confederation currently includes the Air Force's Air Warfare Simulation (AWSIM), the Navy's Research, Evaluation, and Systems Analysis (RESA) model, and the Army's Corps

Battle Simulation (CBS). MTWS has successfully completed Level 0 integration with the ALSP Confederation. This is the first step in allowing the Marine Corps to actively participate in joint wargames. Other models scheduled for integration with the ALSP confederation include the Enhanced Naval Warfare Gaming System (ENWGS), Joint Electronic Combat Electronic Warfare Simulation (JECEWSI), Tactical Simulation (TACSIM), and Combat Service Support Tactical Simulation System (CSS/TSS).

As more of the Services' constructive simulations become object-oriented, interoperability in the future may be provided through a Common Object Request Broker Architecture (CORBA). The development of CORBA is a collaborative industry effort to improve distributed software interoperability. The CORBA specification is designed to provide a standard interface (client/server fashion) between dissimilar object-oriented or object-encapsulated applications on different hardware platforms. CORBA provides a language and operating system, independent, location-transparent interface for passing data request and responses, and the mechanism to dynamically link the server that provides the requested data.

The Army has successfully linked constructive simulations to both live simulations and virtual simulation using DIS protocols. The successful linkage of constructive and live simulation environments was accomplished at the Combat Mission Training Center in training exercises. While live field exercises were ongoing, the adjacent battles were being played within Brigade Battle Simulation (BBS) to train commanders. This linkage permitted battle interaction between the live exercise and the simulation.

The Army is currently evaluating the utility of combining constructive and virtual simulations through the linkage of the Eagle combat model and Battlefield Distributed Simulation-Demonstration (BDS-D). The initial linkage has been the disaggregation/aggregation of the forces in Eagle into the SAFORs in BDS-D. The command and control of the disaggregated forces remain within the Eagle model, while changes in plans and orders are passed through to the BDS-D SAFORs. Artillery units within Eagle respond to calls for fire from friendly BDS-D units on enemy BDS-D units. The procedure to have crewed simulators enter into the battle as the forces are being disaggregated is being developed by the Army.

Artificial Intelligence (AI). Several areas of AI research have matured technologies utilized by the Army M&S community to portray more realistic complex decision-making processes in order to provide better behavior representations. Among these are the Eagle model and associated Adversarial Planner, and the Intelligence Preparation of the Battlefield (IPB) process. The Marine Corps is developing MWARS.

AI knowledge-based systems are currently used to replicate the decision-making processes of commanders and their staffs. Terrain analysis, COA analysis, and situation analysis based on standard military decision factors are all automated features of current combat models provided through the use of AI-based systems. Other applications include fully automated planning capabilities that generate operations orders and contingencies for all subordinate units. These applications are designed to monitor, analyze, and modify subordinate orders based on the changing operational situation. Other efforts in this area include the use of neural network technology to evaluate and recognize patterns of activity on the battlefield associated with the IPB process, and the use of neural networks and fuzzy-logic control techniques to simulate tactical decision making based on doctrinal principles.

System, unit, and mission representation. The capabilities of current constructive models to effectively support the planning, training, and systems acquisition to meet projected future threats are limited. The range of missions covered and doctrine represented by models is similarly limited. The fidelity of current logistics modeling is unsatisfactory as is the modeling of intelligence assets, and command and control. No model currently exists that addresses littoral warfare and maneuver warfare from the sea, an area of particular concern for the Marine Corps. It appears that the new generation of constructive models currently being developed or planned for development will address at least some of these short comings.

MWARS is being developed by the Marine Corps to replace the Amphibious Warfare Model, and specifically addresses operational maneuver from the sea. MWARS will simulate in detail the events surrounding an amphibious landing. It will cover the period starting when the amphibious ships move within range of the enemy coastline, continue through the ship-to-shore movement and the combat associated with the assault objectives, and end with the

success or failure of the landing. MWARS will be carried out at the level of individual equipment, such as vehicles of all types, heavy weapons such as anti-tank missile launchers, rifle squads, and so on. The effects of logistical support, including maintenance, will be modeled.

MTWS is being developed as the Marine Corps replacement for the Tactical Warfare Simulation Evaluation and Analysis System (TWSEAS). MTWS is a computer assisted tactical command and control training system that provides the MAGTF commander and his staff with a realistic combat environment for them to plan and conduct exercises including air, ground, and amphibious operations. It is designed to support field exercises (FEXs) involving combat units, Command Post Exercise (CPXs) with staffs, and exercises involving combinations of live and simulated units. MTWS is the Marine Corps interface to the joint simulation community.

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Section A.3
Technology Assessment: Virtual Simulations

Marine Corps virtual simulation technology development efforts focus on three specific areas: software technologies to support environmental representations; behavioral representations; and hardware technologies supporting simulators.

Technologies that support virtual simulation are among the most widely pursued in the M&S community today. Virtual simulation-specific development efforts fall into three categories: environmental representations; behavioral representation; and virtual simulator hardware. Figure A-5 highlights the specific hardware and software technologies that support virtual simulation requirements. While the Marine Corps will leverage other efforts to the maximum extent, some specific technical requirements should be pursued directly in order to fit virtual simulation to the unique nature of the Marine Corps missions.

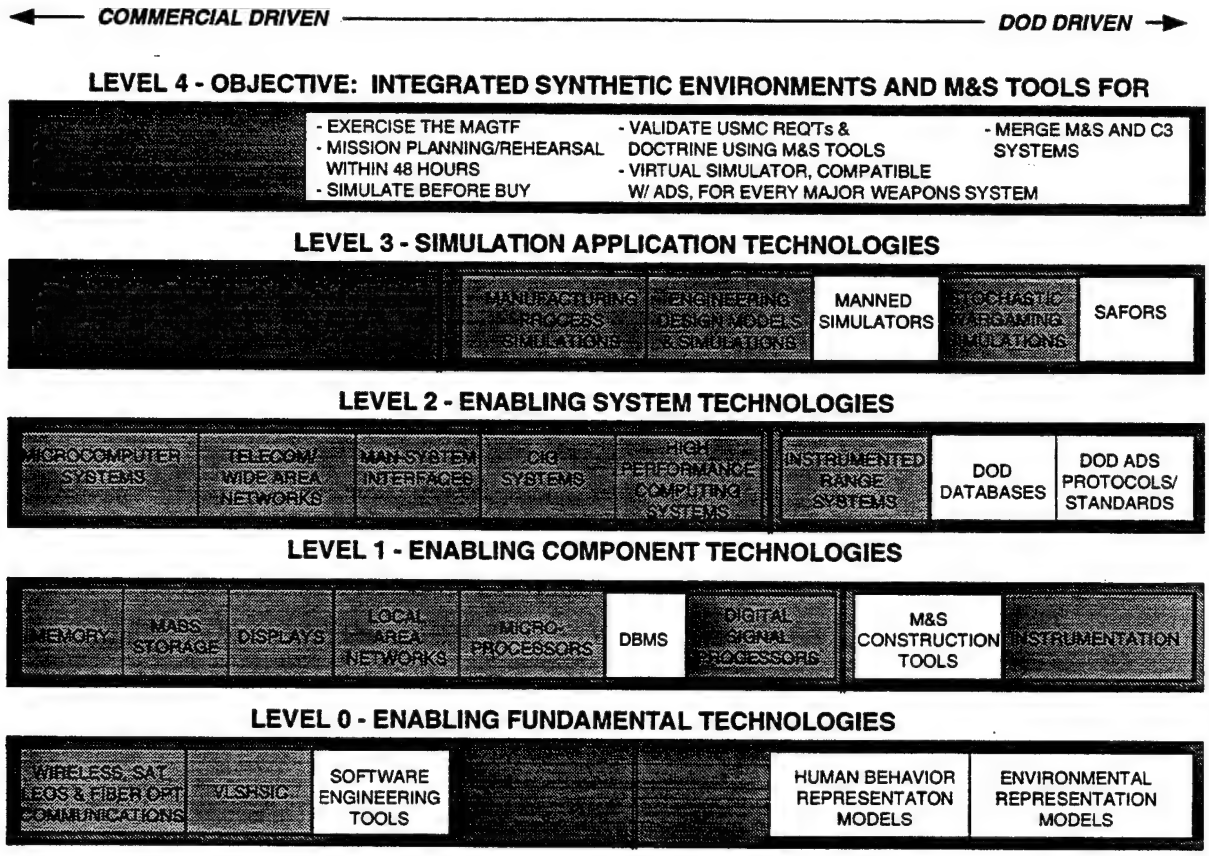

Figure A-5. Technology Assessment for Marine Corps Virtual Simulations

Section A.3.1
Technology Assessment: Environmental Representations

The Marine Corps will develop dynamic terrain representations to meet its unique training, analysis, and operational M&S needs. Where possible, the Marine Corps will use existing databases. However, it will need to be aggressive in developing or influencing the development of synthetic environments particularly important to the Marine Corps.

Environmental representations provide Marine Corps ADS environments realistic, dynamic virtual "worlds." They provide Marine Corps M&S users accurate terrain and realistic weather and combat effects in their virtual simulations. Technology efforts focus on providing variable levels of resolution for different users and missions, representing a variety of terrain types, providing tools to rapidly generate high resolution 3-D representations, and accurate models of dynamic environmental effects. Much work has already been done in the other Services, elsewhere in the government, in industry, and in academia. However, the Marine Corps will need to take the lead in developing environments unique to its mission (i.e., littoral terrain), and will need to be a vocal participant in the development of joint environmental areas such as urban terrain and other environments for the individual combatant and tools for rapidly generating 3-D representations. Figure A-6 illustrates the specific technologies supporting these efforts to build environmental representations for Marine Corps virtual simulations.

Levels of resolution. Other Services efforts to build generic environmental representations for crew-served weapons, air combat, and integrated weapons training appear adequate to meet Marine Corps needs. Marine Corps requirements are providing the push for the highly detailed synthetic environments. ARPA is currently involved in an effort to digitize in detail the Range 400/Delta Corridor at MCAGCC for the M/ETC. This effort will provide the Marine Corps with a baseline capability for individual combatants; however, development efforts still need to be pursued for highly detailed representations of other types of terrain.

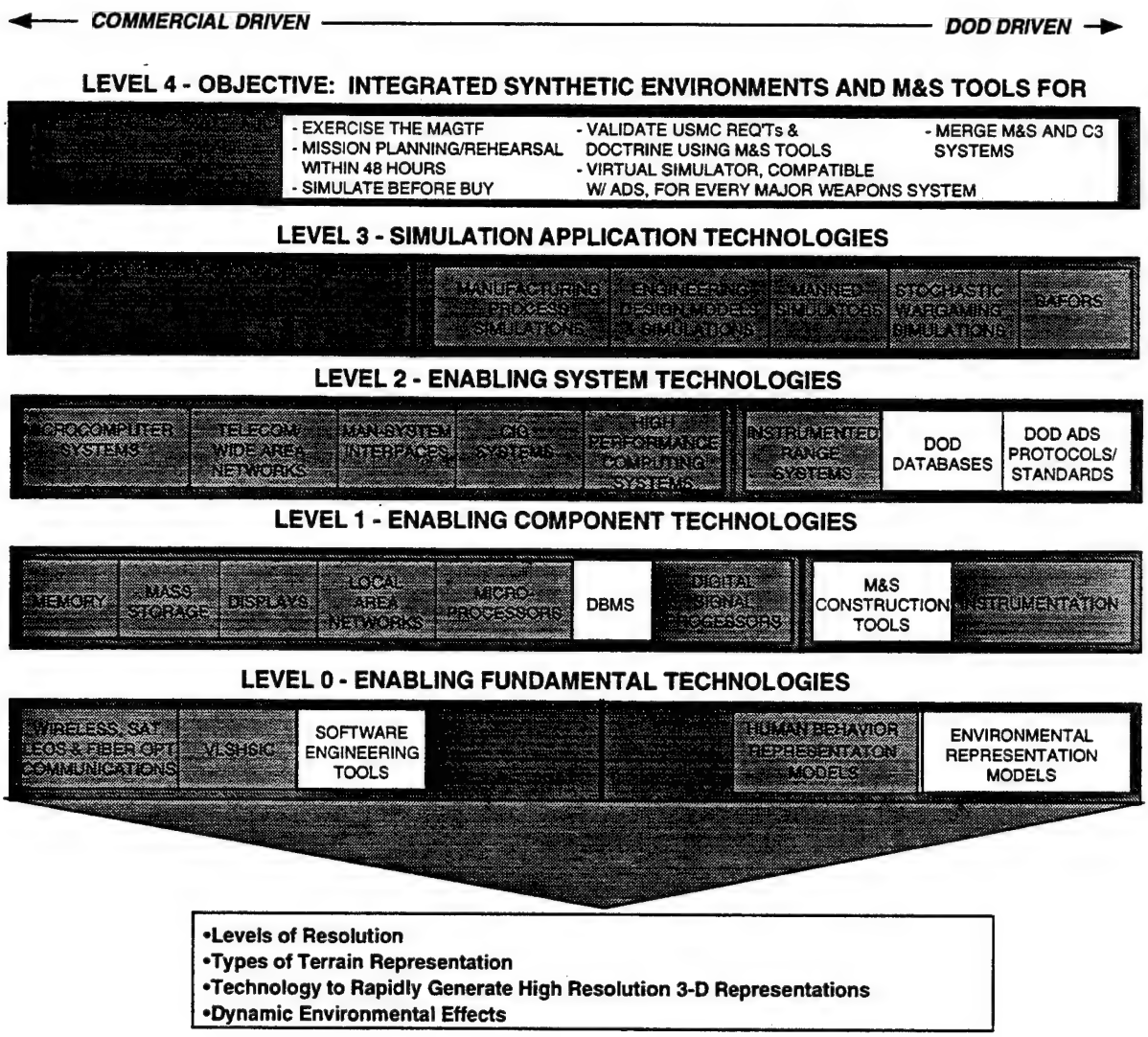

Figure A-6. An Assessment of Environmental Representation Technologies for Marine Corps Virtual Simulations

In particular, the Marine Corps needs to develop sample representations of coastal terrain for amphibious training purposes. The Defense Mapping Agency (DMA) has funded NRL/SSC to develop a littoral warfare layer to the Digital Nautical Chart (DNC). Area of coverage will be a 30 nautical mile by 30 nautical mile area within the Norfolk, VA LWTC area. While the

Air Force and Army are developing tools for rapidly building environments for mission planning and rehearsal, they are either not to the level of resolution (Air Force flight planning tools don't model down to the sub-meter scale) or capable of the size and scope (Army/Joint special operations tools develop models of operational areas of small teams only) needed by the Marine Corps. The Marine Corps sponsored Team Tactical Engagement Simulator (TTES) ATD augmented by DMSO Focused Call 94 project, "Environmental Representation for Urban Terrain," being performed by NAWC-TSD and Argonne National Laboratory, should provide adequate urban terrain models for individual combatants. The STRICOM sponsored work by the Institute for Simulations and Training (IST) should provide adequate terrain models for the mechanized battlefield. Both will need to be expanded and adapted to completely meet long-term Marine requirements (see below).

Types of terrain representation. As previously mentioned, a portion of the MCAGCC is currently being digitized in detail for Marine training to include the individual Marine. Generic and actual terrains have been created for large portions of the world, although in many cases the model data consists only of terrain elevation and, perhaps, vegetation coverage. Much of the current effort within DOD (Marine Corps included) is given over to modeling continental United States (CONUS) land-based training ranges. Most terrain representations appropriate to armored and mounted infantry combat, feature open terrain with little vegetation. A strong reason for this emphasis has been technical constraints. These types of terrain are the easiest to model, and in the past there has not been the computational or graphic power necessary to generate more detailed terrains at a resolution needed by the Marine Corps. Only recently has the DOD M&S community begun to build synthetic environments for use by individual combatants (for example Military Operations in Urban Terrain (MOUT)). To date, there has been little effort to model terrains specific to Marine Corps operations, such as littoral, riverine, and swamp environments.

The Marine Corps will need to encourage the development of the specific and detailed environments needed to support MOUT. While both civilian law enforcement agencies and special operations forces have developed or are developing synthetic representations of urban terrain, they are limited in scope and style. Early special operations representations provided highly detailed terrain for use by small teams with specific missions. Many of these were for

helicopter flight training of insertion and extraction missions. These can be used by Marines involved in similar operations. The Marine Corps will need to ensure that these terrains also portray the effects of combat on the urban terrain: burned out buildings, rubble, craters, unexploded ordnance, etc. Argonne National Laboratory and IST have an ongoing research project in dynamic terrain, but much of their work is still at the laboratory level. The Marine Corps' TTES ATD augmented by funding from the DMSO Focused Call 94 project, "Environmental Representation for Urban Terrain", is oriented toward providing an adequate initial urban synthetic environment for Marine Corps use at the individual/small unit level. Terrain from civilian law enforcement applications may provide larger areas at less detail, but they only portray American urban environments. The Marine Corps will need to support the development of different styles of urban architecture (e.g., Beirut, Mogadishu). Of specific interest to the Marine Corps would be a library of virtual embassies.

The Marine Corps will need to ensure that efforts are made to digitize a littoral region (either notional or of an actual training/operational area) on which to perform virtual amphibious operations. These virtual terrains will need to include more than just beaches. They should also include man-made littoral features such as obstacles and barriers, oil drilling platforms, docks, and other port facilities. Other terrains, such as riverine, swamp, and mountain areas, are of interest to other Services but have not yet been developed to any great degree.

Technology to rapidly generate high resolution 3-D representations. Until recently, efforts to create 3-D representations entailed months of effort and involved large numbers of personnel. Some tools now exist (both within DOD and industry) that allow the fairly rapid generation of either notional or actual 3-D representations . However, it appears, that these tools, while fast, all require inputs in some form of pre-existing digital database(s). Their rapid generation times do not appear to allow for bringing in data from non-digital sources. While other Services/DOD components are interested in having high resolution 3-D representations readily available, much of the current effort is expended on the creation of large amounts of medium-resolution synthetic environments instead of creating tools that will enable users to rapidly build their own highly detailed data sets. Development efforts are hampered in two primary areas: gathering information about the target area and assembling the data into a correct representation. Data comes from many sources (satellite, aerial

reconnaissance, existing databases, paper maps, blueprints, and even verbal descriptions). Many cannot be readily interpreted into digital form. Because of this, the software tools provided to users to perform these interpretations/creations must be powerful and very flexible. Currently several commercial products and academic demonstration test beds exist that perform these types of functions, but a cursory review indicates that they either can not provide the resolution the Marine Corps requires or they cannot be used to generate a product quickly and with little manpower. Further research will be needed to test them against Marine requirements.

Dynamic environmental effects. The environmental effects on the synthetic battlefield are only now getting greater attention. Virtual flight simulators have long used dynamic environmental effects such as wind, clouds, rain, and day/night transitions, but these have primarily been applied to the lower resolution environments used by high-altitude flight simulation. Existing crew-served weapons simulators of the "SIMNET" (simulation networking) class have crudely modeled dust and smoke effects, and current Army programs under the Combined Arms Tactical Trainer (CATT) effort are advancing these efforts to include realistic weather and obscurant effects. Commercial image generators now take into account seasonal changes. Argonne National Laboratory is involved in modeling dynamic interaction with urban terrain, including the movement of objects and simulating the effects of anti-structural devices, such as breaching charges against a brick wall. A goal of the project is to make the algorithms available for use in other types of environments. The IST, in their "Dynamic Terrain Research" program, is performing laboratory-level software research into modeling such dynamic effects as cratering, vehicle tread marks, the effects of repair efforts, construction, and a variety of weather effects (mud, ice, erosion, flooding). There are currently no adequate efforts to model for the virtual battlefield tidal effects, the sea/shore interface during storms, or the effects of virtual combat on synthetic littoral areas.

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Section A.3.2
Technology Assessment: Behavioral Representations

Accurate models of human behavior will provide Marine Corps M&S users with realistic representations of allied, threat, and neutral/noncombatant forces.

Behavioral representations provide the Marine Corps with virtual simulations of realistic, intelligent and interactive CGFs. While the Marine Corps will be able to adapt developments from other Services and organizations for its own use, we will also need to pursue some specific efforts in order to meet our unique needs. CGFs are not generic. Different types are being designed to represent different kinds of forces, levels of combat, and types of operations. The specific technologies used to support virtual simulation CGFs are illustrated in Figure A-7.

CGFs. Realistic CGFs are a new facet of virtual simulation. In the past, virtual simulators such as flight or tank simulators, focused primarily on exercising the skills of the users (flight maneuvers or gunnery practice). However, CGFs are one of the key elements in realizing the vision for synthetic environments: provide isolated users with a realistic set of allies and enemies with which they can closely replicate an accurate combat environment. Because of this importance, CGFs are receiving significant amounts of attention within DOD and academia (where much of the artificial intelligence research is being conducted). CGFs are still in the very early phases of development and it may be some time before the full benefits they can provide will be available to military users.

Types. Current CGF developments in other Services are focusing on providing realistic operations for virtual crew-served weapons platforms such as tanks and aircraft, and command and control from higher-level constructive model entities. Much of the effort is in replicating basic human actions and reactions, i.e., getting vehicles to move with a modicum of human-style intelligence. Little has been done to replicate the doctrine of any

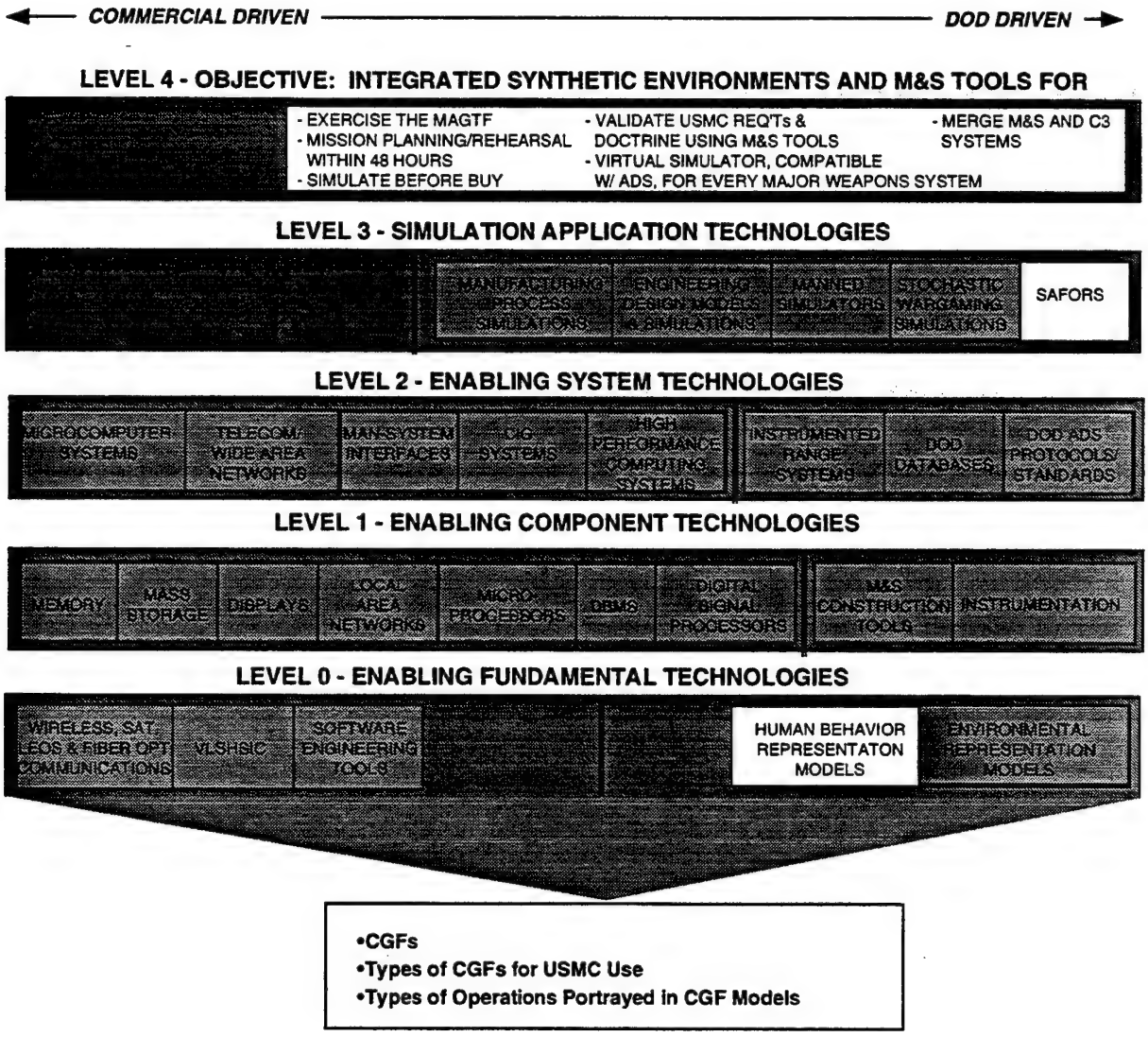

Figure A-7. An Assessment of Behavioral Representation Technologies in Marine Corps Virtual Simulations

particular group (crude Red-team CGFs modeled after generic Soviet doctrines exist, but these are primarily in higher-level, constructive wargames). Efforts are directed primarily at mechanized and aircraft CGFs. While there is some modeling of dismounted units/individual soldiers, it is unclear as to whether this will meet Marine Corps requirements. DOD

modeling of hostile forces is focusing primarily on conventional armored/mechanized units. There is little development of irregular or terrorist forces, or of noncombatants. The Marine Corps may be able to leverage developments in law enforcement and special operations simulators to get both hostile and noncombatant CGF representations of individuals. However, these will need to be modified to meet specific Marine training needs. The ongoing TTES ATD which will be augmented by the DMSO Focused Call 94 project, "Combat Behavioral Representation for Military Operations in Urban Terrain" is addressing the CGF representation of individuals. This ambitious project will provide detailed hostile and neutral CGF models that will accurately represent individuals interacting with trainees on synthetic urban landscapes. The outputs from this project will need to be modified for Marine use in other synthetic environments (particularly the Marine-specific amphibious assault), and the scale of combat activities they can represent may need to be enlarged. The cultural and doctrinal modeling in these CGFs will also need to be expanded in order to meet the contingencies the Marine Corps may face in the future.

Types of operations portrayed. The Marine Corps should be able to easily adapt CGFs being designed for Army ground combat simulations to meet its training and analysis needs in that area. Special operations and civilian law enforcement simulations will provide CGFs that can be used (with modification) for Marine Corps hostage rescue, counter-terrorist, or counter drug virtual simulations; the law enforcement simulations will also provide CGFs for MOUT simulations. However, these will need to be modified to represent the actions of persons in a (foreign) combat environment versus those of persons in a domestic crime simulation. Almost all virtual CGFs are being designed to either replicate combatants or for use in human-factors analysis. There is little effort to build virtual-level CGFs for combat service support, and the CGFs representing noncombatants in special operations and law enforcement simulations are little more than "non-targets" that must not be harmed.

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Section A.3.3
Technology Assessment: Simulators

The Marine Corps will focus its simulator development on light weight deployable simulation capable of stand-alone and netted operations.

The Marine Corps will be able to employ directly or adapt most of the simulator hardware being developed by other Services. It will need to modify this hardware to match Marine Corps-specific vehicles, and may need to develop hardware for appended/embedded simulators on Marine Corps-specific weapons platforms. Figure A-8 illustrates the specific hardware technologies being pursued to support the development of virtual simulators.

Modular, reconfigurable simulators. There are several efforts within DOD to develop modular and/or reconfigurable virtual simulators for such classes of vehicles as armored, fixed-wing aircraft, and helicopters. These developments seem robust enough to meet Marine requirements, although it remains to be seen whether or not Army vehicle simulators can be adapted to represent Marine Corps specific vehicles (especially those that are amphibious). The final cost of these simulators is also an issue. While it is not nearly as expensive as developing a large suite of platform-specific simulators, it is still not certain that the Marine Corps will be able to afford fielding adequate numbers of even these cost-saving devices.

Fielding virtual simulators. Crew-served weapons trainers, such as those being designed under the CATT programs, can be used directly by the Marine Corps for those platforms/vehicles common to both Services. It seems likely that many of these simulators can also be adapted for Marine Corps-specific platforms, although virtual replication of operation within such Marine-specific environments as an amphibious assault will need to be developed for them. The fielding of embedded or appended virtual simulation capability may be the best alternative to meet Marine cost and portability requirements, but it is currently receiving the least attention. In the future as new combat systems are developed and acquired

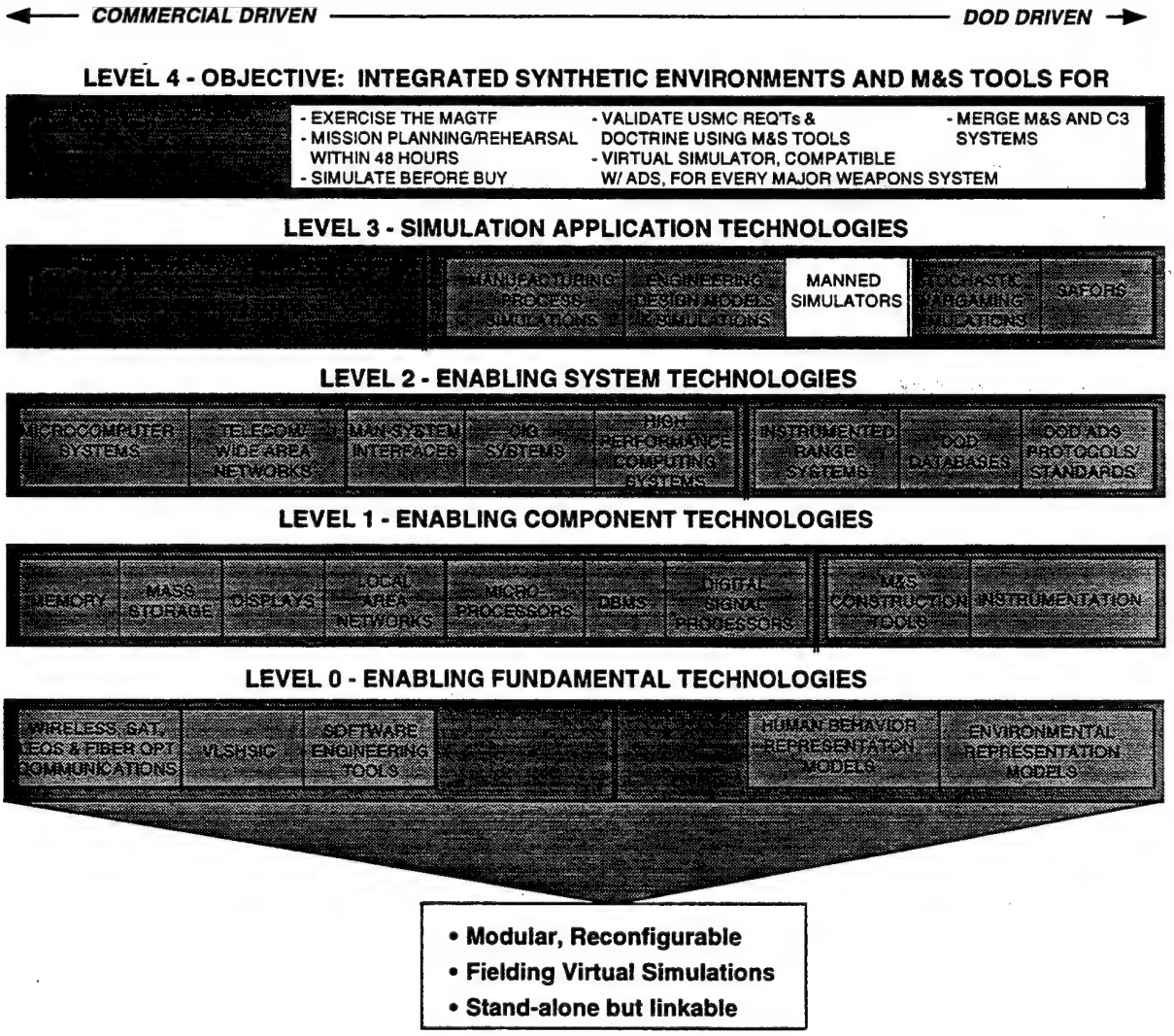

Figure A-8. Technology Assessment for Marine Corps Virtual Simulators

it seems likely that embedded virtual simulation capability will become more common, but if the Marine Corps wants appended simulation capabilities for existing combat systems, there currently are only a few Army programs to leverage.

Stand-alone but linkable simulators. Much of the current effort is in building linked virtual simulations for distributed use on the synthetic battlefield. While these simulators usually have some capability of independent operation, they are designed with distributed operation in mind (e.g., distributed databases, distributed processing, etc.). The Marine Corps will need to ensure that the simulators it acquires have at least a basic set of capabilities supporting the independent use by their users. For example, a helicopter simulator should have a small set of generic terrain, realistic if not perfect flight models, and representative CGFs capable of providing a pilot with realistic hostiles to engage. However, these simulators still require links to the larger ADS world so that their users may realize the benefits of the synthetic battlefield.

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Section A.4
Technology Assessment: Live Simulations

The Marine Corps will leverage its investment in live simulation and focus its efforts in areas that are unique Marine Corps capabilities.

The Army, Navy, and Air Force are involved with existing and developing technologies that can contribute to the Marine Corps live simulation requirements and present opportunities for leveraging. Areas comprising live simulation such as field and system instrumentation, simulated threat signatures, interoperability, and networks are all in some degree of development or employment in at least one of the other Services. The biggest obstacles to fully integrating live simulation into ADS developments are the ability to synchronize real and synthetic environments (time latency); data uncertainty; time, space, position information (TSPI); and the interoperability that will permit player-to-player interaction between geographically separated ranges without the four tier ADS architecture model currently required for interactive live simulation. The systems described herein merely indicate the technologies that are in use or advanced in their development. This list does not nearly exhaust the total number of existing individual programs and systems. Furthermore, though many of the applications address ship and aircraft functions, the imbedded technology can potentially be applied to Marine Corps ground requirements as well. Figure A-9 highlights specific technologies that support live simulation requirements.

Field and system instrumentation. Field instrumentation systems have been characterized by several significant shortfalls: incompatibility with respect to radio frequency (RF) and waveforms, protocols, data formats, RF spectrum utilization, data rates, update rates, accuracy, lack of standards in the field, and some limited TSPI systems. To help achieve standardization and improve interoperability potential between field instrumentation systems, protocol data unit (PDU) and architecture development efforts are underway under the auspices of the IST, a part of the University of Central Florida, and monitored by DMSO. PDUs correlate with the type of simulation interaction that occurs within the simulation

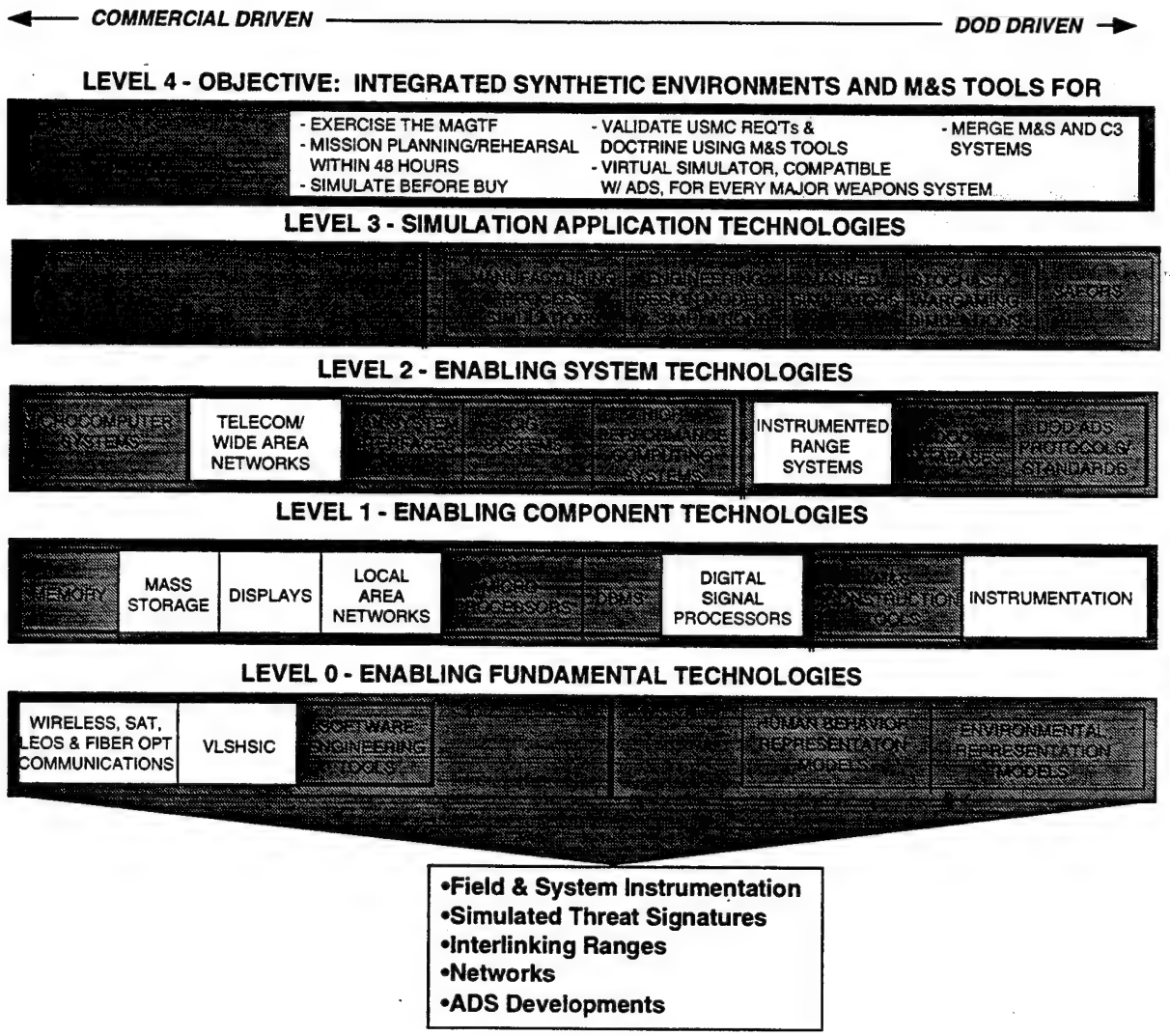

Figure A-9. Technology Assessment for Marine Corps Live Simulations

system. The PDU terminology used to described the ADS model only provides a convenient method of discussing the various activity layers that exist within the simulation and should not be confused with the PDUs normally associated with the communications protocols that are used to exchange data. The ADS model contains four tiers, or PDUs. The first tier, PDU-1, represents the interactions between instrumented player-units (combat personnel and

systems). PDU-2 represents the simulation data that is transferred between the player and the core instrumentation network. The data generated by the player-units are transmitted to the core instrumentation system by RF or terrestrial links for data recording, reduction, analysis, and used for recreating the exercise play for participant debriefing. The third tier, PDU-3, provides the network management functions that must be performed before, during, and after the live simulation exercise. These functions include exercise control; scenario development and implementation; data collection, reduction, analysis, and display and debrief; and any other applicable functions necessary to conduct the live simulation exercise. Because of the dissimilar characteristics of current test and training instrumentation systems, interoperability cannot occur at the PDU-1, PDU-2, or PDU-3 tiers. Because of the inability of dissimilar systems to communicate directly at the PDU-3 and below tiers, constraints on miniaturization of man portable instrumentation, and the current state of simulation techniques, the Field Instrumentation Working Group (FIWG) concluded that a fourth tier (PDU-4) provides the best near-term approach to ensuring DIS interoperability. The PDU-4 provides the gateway that enables incompatible systems to interoperate. The Institute of Electrical and Electronic Engineers 1278-1993 (IEEE 1278) protocol data unit standard establishes a set of standardized PDU types that allows DIS simulations to interact at the PDU-4 tier. The IEEE 1278 provides the PDU gateway interface by converting non-DIS PDUs into DIS-standard PDUs that allow simulations to interoperate. Since player-to-player interaction, player-to-core system, and intra-network interactions can only occur within the host simulation application, this approach provides an indirect capability for dissimilar simulation applications to interoperate.

The Army's National Training Center (NTC), located at Ft. Irwin, CA, has incorporated Range Data Management System (RDMS). RDMS is an electronic training facility upgrade that will provide the NTC an improved data collection capability; integrate GPS with the Special Area Weapons Effects/Multiple Integrated Laser Engagement System (SAWE/MILES) and the Air Ground Engagement System (AGES) player implementation; expand player capacity from 1000 to 2000 participants, with an ultimate goal of 4000 participants; reduce operating and support costs; and provide flexibility to integrate future training systems into the NTC network. Each participant is instrumented with the SAWE (indirect fire assessment), MILES II (ground direct fire), or AGES II (aircraft) simulation

system for force-on-force training engagements conducted on a simulated battlefield (training range). The SAWE/MILES II and AGES II enhance live participant training by providing a direct player-to-player weapons engagement interaction capability (PDU-1) for armored vehicles, aircraft, infantry, artillery, and computer controlled targets and forces. The AGES II and SAWE/MILES II instrumentation supports mine, chemical, and conventional munitions engagements. The weapons fire PDU type is associated with the act of firing and hitting the target during the RDMS engagement through SAWE/MILES II. PDU-2 data elements include player identification, time, events, position dynamics, weapons status, player status, and weapon effects. The network management functions of initialization and termination, player resurrection, and administration and control are handled at the PDU-3 tier. The PDU-4 gateway interfaces with other simulations, including SIMNET and AWSIM. The instrumentation system records individual player engagement events, tracks player movement, and performs weapon engagement casualty assessments that can be replayed for post-exercise debriefs. The RDMS provides a cost effective lessons learned capability that evaluates the effects of command and individual combat decisions without the risk associated with live fire exercises. The RDMS is being designed to be DIS compliant with an initial operational capability (IOC) of August 1994.

The Navy Tactical Combat Training System (TCTS) will provide a multi-warfare training capability to support at-sea, multi-ship, integrated surface, subsurface, and aviation combat training. The TCTS will stimulate aircraft, surface, and subsurface sensor displays with simulated surface, subsurface, and airborne threat targets and record the resulting shipboard interactions for post-exercise debriefing. Another Navy simulation system, the Battle Force Tactical Trainer (BFTT), will be incorporated in the TCTS aboard each participating ship. It will stimulate the ship's sensor displays by providing simulated radar, electronic warfare (EW), and sonar targets that are consistent among all participants across the network. The at-sea TCTS datalink will be provided by a line-of-sight Navy instrumentation data network that is separate from the tactical communications network. Satellite communications (SATCOM) will be used for connecting the deployed TCTS assets with shore facilities. Aircraft sensor systems are planned to be stimulated by onboard instrumentation contained in training pods mounted to the aircraft. TCTS will have the capability to interface with fixed training ranges such as the Tactical Aircrew Combat Training System (TACTS) range at Naval Air Station

(NAS) Fallon, the Atlantic Fleet Weapons Training Facility (AFWTF), and the Pacific Missile Range Facility (PMRF). In addition, the BFTT is planned to interoperate with the MTWS. TCTS is designed to be DIS compliant and has an IOC of FY 2000.

The Mobile Automated Instrumented Suite (MAIS) is an Army mobile field instrumentation system designed to support operational and force development testing by providing a real-time casualty assessment (RTCA) capability. The system instruments players participating in simulated tactical engagements during a live simulation exercise. Using GPS, the system provides tracking of dismounted personnel, vehicles, rotary and fixed-wing aircraft, and crew served weapons. During direct fire events using MILES and AGES II, the player-unit's instrumentation exchanges engagement information which allows the target player-unit to calculate its casualty status based on Army Material Systems Analysis Activity (AMSAA) weapons effects tables. The casualty information is real-time datalinked to the supporting C3 center using the system's time division multiple access (TDMA) network. Since the MAIS is mobile, it can be deployed to other geographical locations in support of weapons effectiveness testing and force-on-force exercises. The MAIS communications network provides direct communications between the player-unit's instrumentation and the C3 center for data transfer via a tower relay system. The C3 center is a sheltered complex that consists of a central instrumentation facility, test control center, software support facility, and a maintenance and battery storage shelter. IOC is planned for January 1997 at Ft. Hood, TX, to support 130 participants. The MAIS will eventually consist of four C3 centers, each capable of supporting a total of 1830 players operating in a 50 km by 50 km area. The MAIS software is being written in the Ada programming language. The system is being designed to be DIS compliant.

Mulltilateration tracking systems can have limitations such as update rates, line-of-sight, and the number of participants. Use of GPS for TSPI will enhance the quality of TSPI systems. Most future instrumentation systems will rely on the GPS to derive positions. The Marine Corps' Position Location Reporting System (PLRS) is another TSPI capability that enhances live simulations. PLRS is intended to interface with MTWS, permitting MTWS to request position data on all PLRS-equipped units participating in an exercise. GPS and PLRS accuracies are adequate for most applications. However, when the results of a live simulation

exercise are used with virtual simulations, even small errors can be significant. In a live simulation exercise a dismounted Marine may be using a tree or some other terrain feature to provide cover. If the terrain database used in the virtual simulation does not accurately represent the live terrain characteristics, the dismounted Marine might be portrayed as being without cover. This type of error produces misleading test or training results. This problem can be minimized by use of the common mode of GPS operation.

Sources of simulated threat signatures. As described earlier, the Navy's BFTT produces simulated signatures of threat surface, subsurface, and airborne targets to stimulate radar, sonar, and EW systems.

The Air Force Real-Time Electronic Digitally Controlled Analyzer Processor (REDCAP) is a simulation facility in Buffalo, NY, that provides high-fidelity, RF, hardware- and human-in-the-loop simulation of a threat Integrated Air Defense System (IADS). The REDCAP system is used to evaluate the effectiveness of integrated weapon system electronics and tactics to defeat or degrade an IADS capability to detect, track, and engage targets. It can provide evaluation of electromagnetic countermeasures (ECM) system effectiveness against ground, naval, and airborne radar, ground control intercept, early-warning radar, and RF voice and data communications. The REDCAP system can support Developmental Test and Evaluation (DT&E) and supplement operational T&E (OT&E) by integrating realistic, real-time, simulated IADS test scenarios in the evaluation of weapon system ECM characteristics, guided weapon testing, and integrated aircraft weapon platforms.

The Air Force Electronic Warfare Evaluation Simulator (AFEWES), located at Ft. Worth, TX, provides high-fidelity electronic signature simulation of the SA-2 through SA-16 missiles, AIM-9 air-to-air missiles, the Fulcrum, Flanker, and Foxhound airborne interceptors, the infrared characteristics of aircraft engines and countermeasures equipment, and can generate realistic dense RF environments to evaluate airborne radar warning receivers and power-managed ECM equipment. The AFEWES can also provide simulation support for DT&E and OT&E by creating realistic, real-time, threat weapon system test scenarios, which can induce the human-in-the-loop to operate the test weapon system at a level consistent with an actual combat environment.

Interlinking ranges and sources of simulated threat signatures. Instrumented tests and exercises are performed at various ranges and facilities designed specifically for these purposes. These facilities were developed independently without regard for interoperation with other ranges and simulations not directly supporting the facility. The result is limited interoperability between ranges, facilities, and simulation systems. Some common instrumentation packages have been developed, but most systems are unique. New instrumentation systems employing technologies such as GPS, should increase standardization, commonality, and interoperability between instrumentation and simulation systems.

Data transmission incompatibilities present one major obstacle to achieving interoperability. The field instrumentation system architecture framework (FISAF) was established by the field instrumentation working group comprised of representatives from the U.S. Army Simulation, Training, and Instrumentation Command (STRICOM), IST, and DMSO. The FISAF addresses the ability to internet training ranges, test facilities, laboratories, service schools, and industry facilities and how to make them DIS compatible. Specific issues being examined are: high communication bandwidth requirements, traffic volumes, and types and methods of data transmission. Furthermore, existing and developing sources of simulated threat signatures are planned to interlink with instrumented ranges.

Networks. Current training systems operate within latency rates dictated by the training or T&E range application. Performance in the milliseconds range may not adequately support some requirements such as testing a TDMA network. To achieve real-time inter-range transfer of test data, the Air Force Development Test Center (AFTDC) projected near term data transfer requirements to be characterized by data rates of 45 - 100 megabits per second and latency rates in the millisecond to microsecond range depending on transmission distance. Far term data transfer rates are projected to be in the 100 megabits per second to one Gigabit per second range with latency rates minimized by use of terrestrial circuits where needed.

The DSI, intended to be a worldwide network, is used for distributed high-speed simulation and wargaming at simulation sites among the Joint uniformed Services. On an experimental

network sponsored by ARPA, 67 nodes were implemented in phases during 1989-1991. Expansion plans call for the network to grow to as many as 86 nodes. An examination of current DSI sites reveals it to be a significant and greatly dispersed operational network, with clusters of sites in Washington, Los Angeles, and other cities throughout CONUS. DSI supports various distributed wargaming and simulation applications that resemble those supported by DIS, as well as stream-based packet video and voice exchanges among sites. (Stream protocols emphasize speedy delivery, occasionally dropping small amounts of data to maintain a steady flow or stream of data.) In addition, DSI supports off-the-shelf virtual terminal (Telnet), file transfer (FTP), and electronic mail (SMTP) protocols. Although DSI uses MIL-STD 1777 and 1778 (DOD transmission control protocol and internet protocol), it also depends on a proprietary stream protocol (ST-II) developed by Bolt, Beranek, & Newman (BBN) for and implemented almost exclusively on BBN's T-20 gateway. The network also implements the host access protocol (HAP) and ALSP. DSI is capable of conducting SECRET end-to-end encryption (E3) exchanges among attached hosts using the Motorola Network Encryption System (NES). Future expansion of the network includes plans to upgrade backbone links from current T-1 service (1.544 megabits per second) to T-3 service (45 megabits per second). Like most modern high-speed networks, DSI is evaluating a future shift to ATM or "cell" switching. (A cell is a small, fixed-length data packet that a network can handle more quickly because of its predictable size.) DSI planners intend to eventually implement the U.S. Government Open Systems Interconnection Profile (GOSIP), and are already considering integration with the Defense Information System Network (DISN).

The Joint Interoperability Testing Center (JITC) Defense Information System Testbed Network is sponsored by DISA and managed by the JITC at Ft. Huachuca. Joint service users, the National Security Agency (NSA), and the Department of State (DOS) are its primary users. Composed entirely of reconfigurable T-1 lines, the JITC network provides voice and data communications facilities for interoperability testing of tactical communications systems for its users at 20 currently operational sites in southern CONUS, including Camp Pendleton. Originally built to support TRITAC testing, the JITC network now supports data, voice, and video teleconferencing. This network allows SECRET data

exchange between sites using the BLACKER E3 system for packet data, as well as KG-84 link encryption. It is not DIS compliant.

The Test and Evaluation Range Internet System (TERIS) is intended exclusively for T&E users. When implemented, the network will connect from seven to nine of the major range test facility bases (MRTFB). Three nodes, Pt. Mugu, CA, Ft. Huachuca, and Eglin AFB, FL, are scheduled to be available for limited system IOC during FY94. TERIS will support DIS protocols. As a special note, TERIS plans to provide network service to locations that may not be served by the other networks mentioned above. At first, TERIS will probably concentrate on implementing protocols developed by the inter-range instrumentation group (IRIG), but it is likely that other off-the-shelf protocols will be added to deliver additional functionality to the test ranges. Classified data and voice exchanges will probably be implemented using trunk encryption devices, rather than E3 devices. Because the final architecture has not been determined for TERIS, it may have the most flexibility of the networks described in this section.

ADS developments. Interfacing instrumented ranges and systems with distributed models and simulations is perhaps the most difficult challenge of creating a credible, seamless synthetic environment. System architectures that integrate instrumented ranges and systems with virtual and constructive models and simulations must address synchronizing real and synthetic environments, resolving differences in the fidelity of real and synthetic environments, the credible projection of instrumented entity information into a virtual or constructive environment, and the reverse. Standards, procedures, and an architecture for injecting the behavior of range entities into a synthetic environment do not exist. An even bigger obstacle is the projection of events created in a virtual or constructive simulation onto an instrumented range. Existing instrumented ranges are not designed to inject synthetic entities. A potential near term fix to this problem is a system called INFOSCOPE. A prototype of what could become a family of mechanisms for instrumenting live simulations, INFOSCOPE is a man-portable mechanism designed to add units or facilities generated from a constructive or virtual simulation. It consists of an eye-piece that clamps onto an observation device or weapon sight which injects into its field of view an icon representing any object generated by the constructive or virtual simulation, when the observer has

established line of sight and the object is within range. Future systems are aimed at allowing the actions of entities in a synthetic environment to be sent over WANs using DIS standard protocol to a control node that will redistribute the information in a standard protocol directly to platform sensors. Developing technology, such as the GPS, digital communication links, position and orientation transducers, velocity and acceleration sensors, and advanced displays makes it possible to convert the real-time operating parameters of a live weapon system into electronic inputs that represent the real system in a virtual or constructive simulation. Field instrumentation interface goals have been established by the FIWG for T&E, and training and mission rehearsal. The near term goal (within one year) is live-to-virtual interface in the beyond-line-of-sight (BLOS) region. The mid-term goal (within two years) is live-to-live and live-to-constructive interfaces in the within-visual-range (WVR) and BLOS regions. The long term goal (beyond two years) is live-to-virtual interface in the WVR region.

Appendix B
Procedures and Guidelines for Verification, Validation, and Accreditation

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Appendix C
Procedures and Guidelines for Configuration Management of Marine Corps Models and Simulators

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Appendix D
Marine Corps Modeling and Simulation Catalog

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GLOSSARY

ACRONYMS

ACMC	Assistant Commandant of the Marine Corps
ADS	Advanced Distributed Simulation
AFEWES	Air Force Electronic Warfare Evaluation System
AFOR	Automated Force
AFTDC	Air Force Development Test Center
AFWTF	Atlantic Fleet Weapons Training Facility
AGES	Air-Ground Engagement System
AI	Artificial Intelligence
ALSP	Aggregate Level Simulation Protocol
AMSAA	Army Materiel Systems Analysis Agency
ARPA	Advanced Research Projects Agency
ATD	Advanced Technology Demonstration
ATM	Asynchronous Transfer Mode
Avn	Aviation
AWSIM	Air-Warfare Simulation
AWT	Amphibious Warfare Technology Directorate, MARCORSYSCOM
BBN	Bolt, Beranek, and Newman
BBS	Brigade Battle Simulation
BDS-D	Battlefield Distributed Simulation-Demonstration
BFTT	Battle Force Tactical Trainer
BLOS	Beyond-Line-of-Sight
C3	Command, Control, Communications
C3I	Command, Control, Communications and Intelligence
C4I	Command, Control, Communications, Computers and Intelligence
CASE	Computer-Aided Software Engineering
CATT	Combined Arms Tactical Trainer
CBS	Corps Battle Simulation
CDP	Combat Development Process
CG, MCCDC	Commanding General, Marine Corps Combat Development Command
CGF	Computer Generated Force

CIG	Computer Image Generator
CINC	Commander-in-Chief
CJCS	Chairman, Joint Chiefs of Staff
CM	Configuration Management
CMC	Commandant of the Marine Corps
COA	Course of Action
CONUS	Continental United States
CORBA	Common Object Request Broker Architecture
COTS	Commercial Off-the-Shelf
CPX	Command Post Exercise
CRT	Cathode Ray Tube
CSPAR	CINCs Preparedness Assessment Report
CSS/TSS	Combat Service Support Tactical Simulation System
DBMS	Database Management System
DDR&E	Director, Defense Research and Engineering
DIS	Distributed Interactive Simulation
DISA	Defense Information Systems Agency
DISN	Defense Information System Network
DMA	Defense Mapping Agency
DMSC	Decision Making Support Center
DMSI	Defense Modeling and Simulation Initiative
DMSO	Defense Modeling and Simulation Office
DNC	Digital Nautical Chart
DOD	Department of Defense
DOS	Department of State
DPG	Defense Planning Guidance
DRAM	Dynamic Random Access Memory
DSI	Defense Simulation Internet
DT&E	Developmental Test and Evaluation
E3	End-to-end Encryption
ECM	Electronic Countermeasures
ENWGS	Enhanced Naval Warfare Gaming System
ESG	Executive Steering Group
ETMO	Education, Training, and Military Operations
EW	Electronic Warfare
EXCIMS	Executive Council for Modeling and Simulation
FEX	Field Exercise
FFRDC	Federally Funded Research and Development Center

FISAF	Field Instrumentation System Architecture Framework
FIWG	Field Instrumentation Working Group
FMF	Fleet Marine Force
FONS	Fleet Operation Needs Statement
FTP	File Transfer Protocol
GOSIP	U.S. Government Open Systems Interconnection Protocol
GOTS	Government Off-the-Shelf
GPS	Global Positioning System
GUI	Graphical User Interface
HAP	Host Access Protocol
HMD	Helmet Mounted Display
HQMC	Headquarters, Marine Corps
I&L	Installation and Logistics
IAC	Information Analysis Center
IADS	Integrated Air Defense System
IEEE	Institute of Electrical and Electronic Engineers
IG	Inspector General, HQMC
IOC	Initial Operational Capability
IPB	Intelligence Preparation of the Battlefield
IPL	Integrated Priority List
IRIG	Inter-Range Instrumentation Group
ISDN	Integrated Services Data Network
IST	Institute for Simulation and Training
JECEWSI	Joint Electronic Combat Electronic Warfare Simulation
JITC	Joint Interoperability Test Center
JMSEP	Joint Modeling and Simulation Executive Panel
JWFC	Joint Warfighting Center
LAN	Local Area Network
LCD	Liquid Crystal Display
LEOS	Low Earth Orbiting Satellite
LFTC	Landing Force Training Command
LWTC	Littoral Warfare Training Center
M&RA	Manpower and Reserve Affairs Department, HQMC
M&S	Modeling and Simulation

M/ETC	MAGTF Expeditionary Training Center
MAA	Mission Area Analysis
MAGTF	Marine Air-Ground Task Force
MAIS	Mobile Automated Instrumentation Suite
MARCORSYSCOM	Marine Corps Systems Command
MARFORLANT	Marine Forces Atlantic
MARFORPAC	Marine Forces Pacific
MARRESFOR	Marine Reserve Forces
MAWTS	Marine Aviation Weapons and Tactics Squadron
MCAGCC	Marine Corps Air-Ground Combat Center
MCCDC	Marine Corps Combat Development Command
MCCTA	Marine Corps Computer and Telecommunications Activity
MCIA	Marine Corps Intelligence Activity
MCLLS	Marine Corps Lessons Learned System
MCMP	Marine Corps Master Plan
MCMSMO	Marine Corps Modeling and Simulation Management Office
MCMSWG	Marine Corps Modeling and Simulation Working Group
MCOTEA	Marine Corps Operational Test and Evaluation Activity
MCTSSA	Marine Corps Tactical System Support Activity
MCU	Marine Corps University
MEF	Marine Expeditionary Force
MILES	Multiple Integrated Laser Engagement System
MOUT	Military Operations in Urban Terrain
MRTFB	Major Range Test Facility Base
MSTP	MAGTF Staff Training Program
MSWG	Modeling and Simulation Working Group
MTWS	MAGTF Tactical Warfare Simulation
MWARS	Maneuver Warfare Analytical and Research System
NAS	Naval Air Station
NAWC-TSD	Naval Air Warfare Center-Training Systems Division
NEF	Naval Expeditionary Force
NES	Motorola Network Encryption System
NGREA	National Guard and Reserve Equipment Appropriation
NSA	National Security Agency
NTC	National Training Center
OOD	Object-Oriented Design
OOP	Object-Oriented Programming
OT&E	Operational Test & Evaluation
OMFTS	Operational Maneuver from the Sea

P&L	Production and Logistics
P&R	Plans and Requirements, HQMC
PDU	Protocol Data Unit
PLRS	Position Location Reporting System
PMRF	Pacific Missile Range Facility
POM	Program Objective Memorandum
PP&O	Plans, Policies, and Operations Department, HQMC
PPBS	Planning, Programming, and Budgeting System
R&D	Research and Development
RAP	Remedial Action Program
RDMS	Range Data Management System
REDCAP	Real-Time Electronic Digitally Controlled Analyzer Processor
RESA	Research, Evaluation, and System Analysis
RF	Radio Frequency
RTCA	Real-time Casualty Assessment
SAFOR	Semi-Automated Force
SATCOM	Satellite Communications
SAWE/MILES	Special Area Weapons Effects/Multiple Integrated Laser Engagement System
SEMP	Supporting Establishment Master Plan
SIMNET	Simulation Networking Program
SMTP	Simple Mail Transfer Protocol
SONET	Synchronous Optical Networks
STOW	Synthetic Theater of War
STRICOM	Simulation, Training, and Instrumentation Command (U.S. Army)
SWG	Sub Working Group
TF	Task Force
T&E	Test and Evaluation
TACSIM	Tactical Simulation
TACTS	Tactical Aircrew Combat Training System
TCTS	Tactical Combat Training System
TDMA	Time Division Multiple Access
TERIS	Test and Evaluation Range Internet System
TSPI	Time, Space, Position Information
TWSEAS	Tactical Warfare Simulation Evaluation and Analysis System

USD(A)	Undersecretary of Defense for Acquisition
VLSHSIC	Very Large Scale High Speed Integrated Circuitry
VV&A	Verification, Validation, and Accreditation
WAN	Wide Area Network
WCSD	Wargaming and Combat Simulation Division
WDID	Warfighting Development Integration Division
WVR	Within-Visual-Range

DEFINITIONS

Accreditation	An official certification that a model or simulation is acceptable for use for a specific purpose.
Aggregated Level Simulation Protocol	Mechanism and protocols to interface dissimilar constructive models and simulations.
Combat Service Support Element	The MAGTF element that is task organized to provide the full range of combat service support necessary to accomplish the MAGTF mission.
Computer Generated Forces	A collection of unmanned battlefield entities under control as a unit. CGF replace or supplement friendly, enemy or neutral manned simulators during a specific session. If a platform level simulation entity is directly controlled by a man in the loop it is a semi-automated force (SAFOR), if it is directly controlled by a computer it is an automated force (AFOR)
Configuration Management	The application of technical and administrative direction and surveillance to identify and document the functional and physical characteristics of a model or simulation, control changes, and record and report change processing and implementation status.

Constructive Model or Simulation	Wargames, models and analytical simulations that typically involve aggregated software representations of real world entities or systems, their behavior, and associated outcomes.
Defense Simulation Internet	DMSO sponsored terrestrial pipeline (wide band packet switching) for the distribution of simulations, and designed to be the test bed for defense simulation networking.
Distributed Interactive Simulation	(1) Any combination of virtual, constructive, and live simulations that are distributed over a network and interact through standardized protocols. (2) IEEE Standard 1278 protocols.
EXCIMS	An organization established by the Under Secretary of Defense (Acquisition) (USD(A)) and responsible for providing advice and assistance on DOD M&S issues. Membership is determined by the USD(A) and is at the Senior Executive Service, general/flag officer level.
Fidelity	The degree to which aspects of the real world are presented in models and simulators.
Global Grid	A world wide network that provides data communications that support advanced distributed simulation. Services provided included packet switching, data link sharing, alternate routing, and virtual dedicated circuits.
Joint	For the purpose of this publication, "joint" refers to those M&S items and activities that share participation or support of more than one Service.
Local Area Network	A class of data network which provides high data rate interconnection between network nodes in close physical proximity. LANs are defined by the IEEE 802.X series of standards

Live Simulation	A representation of military operations using military personnel and instrumented real equipment which simulate experiences achieved during actual operational conditions. Typical live simulations are operational testing or Combined Arms Exercises at MCAGCC.
Marine Air-Ground Task Force	A task organization of Marine forces under a single command and structured to accomplish a specific mission. The MAGTF elements will normally include command, aviation combat, ground combat, and combat service support.
Mission Rehearsal	Practicing planned tasks and functions critical to mission success using a true-to-life, interactive representation of the predicted operating environment.
Model	A physical, mathematical, or other logical representations of a system, entity, phenomenon, or process.
Open System Environment	The fielding of hardware and software products that are interoperable and portable. The objective is to promote competition by allowing systems developed by multiple vendors and nations to interoperate through a common set of computer and communication protocols.
Operational Maneuver From the Sea	The application of the principles of maneuver warfare to operations in a maritime environment. The concept of Operational Maneuver From the Sea optimizes the flexibility to project power from the sea landward through a variety of means.
Protocol Data Unit	A structured message which transfers essential data of a specific type from one simulation entity to another and allows them to participate in a common exercise.

Proponent	The agency or organization that has primary responsibility for the life cycle of an assigned model or simulation.
Resolution	The degree of detail and precision used in the representation of real-world aspects in a model or simulation.
Simulation	A method for implementing a model over time and a technique for testing, analyzing, or training in which real-world systems are used, or real-world and conceptual systems are emulated by a model.
Synthetic Environment	Computer generated representation of the real world.
T-1	Data communications service that supports 1.544 megabits per second operation.
T-3	Data communications service that supports 45 megabits per second operation.
Validation	The process of determining the extent to which a model or simulation is an accurate representation of the real-world from the perspective of the intended use of the model or simulation.
Verification	The process of determining that model or simulation implementation accurately represents the developer's conceptual description and specifications. Verification evaluates the extent to which the model or simulation has been developed using sound and established software engineering techniques.
Virtual Modeling and Simulation	Synthetic representation of warfighting environments envolving manned simulators that

	are patterned after the simulated organization or systems and actual military operations.
Waveform	Term used to define the composite modulation and signaling used on RF communication links.